POTENTIAL CONTAMINANT LOADINGS TO THE NIAGARA RIVER FROM CANADIAN WASTE DISPOSAL SITES

JANUARY 1991

Ontario
Environment
Environnement

92-01641/

ISBN 0-7729-7997-9

POTENTIAL CONTAMINANT LOADINGS TO THE NIAGARA RIVER FROM CANADIAN WASTE DISPOSAL SITES

Report prepared by:
Monenco Consultants Limited
180 Attwell Drive, Suite 400
Rexdale, Ontario
M9W 6A9

Report prepared for:

Ontario Ministry of the Environment

JANUARY 1991
Reprinted JULY 1991

Cette publication technique
n'est disponible qu'en anglais

Copyright: Queen's Printer for Ontario, 1991
This publication may be reproduced for non-commercial purposes with appropriate attribution

PIBS 1266E2

FOREWORD
by the
Ontario Ministry of the Environment

The interpretation of loadings from landfill sites in Ontario must be made with care. It is difficult to apply one standard methodology to a large number of sites. What may be true in describing conditions at one site may not be particularly valid at another.

Several limitations became apparent during the calculation of loading estimates. The initial methodology, adopted from U.S.-based studies, evolved around the EPA priority pollutant list of 129 chemicals. All chemicals on this list were treated as persistent toxic substances. While this may be true for most of the priority pollutants, some of the chemicals are not persistent toxics. This does not have major implications for the calculations of loadings from the U.S. side; however, it has significant ramifications for the major site on the canadian side.

The major toxic contaminant associated with Ontario-based landfills is Cyanide (98%). Cyanide is an insignificant factor in the loadings from U.S. loading calculations. Cyanide is normally non-persistent and readily degrades in the natural environment to other non-toxic nitrogenous species (nitrates and nitrites) through the processes of biodegradation and photochemical reduction.

It should be noted that, with the exception of cyanide, total pollutant loadings to the Niagara River from Ontario landfills are estimated to represent less than 2% of the estimated loading from the U.S. side. The loading from the Ontario landfills involves only heavy metals; no loading is attributable to organic compounds.

Despite the bias imparted to Cyanide, the Ontario Ministry of the Environment made a commitment to estimate loadings to the Niagara River from Ontario-based waste disposal sites in a manner comparable to that developed by Gradient/GeoTrans for the United States Environmental Protection Agency. The same methodology was adopted by the Ministry's contractor, Monenco Consultants and the results are presented in this report.

TABLE OF CONTENTS

		Page #
Letter of Transmittal		(i)
Table of Contents		(ii)
PART 1 - INTRODUCTION		
1.1	BACKGROUND	1-1
1.2	TERMS OF REFERENCE	1-2
1.3	MONENCO APPROACH	1-3
1.4	PROBLEMS OF APPROACH	1-4
PART 2 - SITE ELIMINATION CRITERIA		
2.1	SITE SELECTION	2-1
PART 3 - CONTAMINANT LOADING CALCULATION METHODOLOGY		
3.1	INTRODUCTION	3-1
3.2	CONTAMINANT CONCENTRATION CALCULATIONS	3-2
3.2.1	Assumptions	3-2
3.2.2	Statistical Significance	3-2
3.3	GROUNDWATER FLUX CALCULATIONS	3-3
3.3.1	Assumptions	3-3
3.3.2	Darcy's Law	3-4
3.3.3	Water Budget	3-4
3.3.4	Comparison of Methods for Estimation of Flux	3-5
3.4	SURFACE WATER LOADINGS	3-6
PART 4 - DATA TREATMENT		
4.1	CHEMICAL DATA	4-1
4.2	HYDROGEOLOGICAL DATA	4-2
4.3	CERTAINTY OF ESTIMATES	4-2
PART 5 - SITE ANALYSES		
5.1	ATLAS STEEL LANDFILL, WELLAND	5-1
5.1.1	Background	5-1
5.1.2	Hydrogeology	5-1
5.1.3	Available Monitoring Data	5-2
5.1.4	Contaminant Concentration Calculations	5-5
5.1.5	Loading Estimate	5-6

TABLE OF CONTENTS (continued)

		Page
5.2	CYANAMID INC. LANDFILL, WELLAND	5-6
5.2.1	Background	5-6
5.2.2	Hydrogeology	5-9
5.2.3	Available Monitoring Data	5-11
5.2.4	Contaminant Concentration Calculations	5-13
5.2.5	Loading Estimate	5-13
5.3	CYANAMID INC. LANDFILLS, NIAGARA FALLS	5-14
5.3.1	Background	5-14
5.3.2	Hydrogeology	5-18
5.3.3	Available Monitoring Data	5-20
5.3.4	Contaminant Concentration Calculations	5-22
5.3.5	Loading Estimate	5-22
5.4	THE BRIDGE STREET LANDFILL, FORT ERIE	5-23
5.4.1	Background	5-23
5.4.2	Hydrogeology	5-27
5.4.3	Available Monitoring Data	5-29
5.4.4	Contaminant Concentration Calculations	5-31
5.4.5	Loading Estimate	5-31
5.5	CNR VICTORIA AVENUE LANDFILL, NIAGARA FALLS	5-34
5.5.1	Background	5-34
5.5.2	Hydrogeology	5-34
5.5.3	Available Monitoring Data	5-35
5.5.4	Contaminant Concentration Calculations	5-35
5.5.5	Loading Estimate	5-36

PART 6 - SUMMARY OF RESULTS

6.1	SUMMARY	6-1

PART 7 - CONCLUSIONS AND RECOMMENDATIONS

7.1	CONCLUSIONS	7-1
7.2	RECOMMENDATIONS	7-2

PART 8 - REFERENCES

APPENDICES

A SITE DESCRIPTIONS OF LANDFILLS NOT INCLUDED IN THE LOADING CALCULATIONS

TABLE OF CONTENTS (continued)

Page #

B DETAILED CALCULATIONS FOR THE ATLAS STEEL LANDFILL, WELLAND
- B1 Contaminant Concentrations
- B2 Groundwater Flux
- B3 Groundwater Loading
- B4 Surface Water Loading
- B5 Total Loading

C DETAILED CALCULATIONS FOR THE CYANIMID INC. LANDFILL, WELLAND
- C1 Contaminant Concentrations
- C2 Groundwater Flux
- C3 Groundwater Loading

D DETAILED CALCULATIONS FOR THE CYANIMID INC. LANDFILLS, NIAGARA FALLS
- D1 Contaminant Concentrations
- D2 Groundwater Flux
- D3 Groundwater Loading
- D4 Surface Water Loading
- D5 Total Loading

E DETAILED CALCULATIONS FOR THE BRIDGE STREET LANDFILL, FORT ERIE
- E1 Contaminant Concentrations
- E2 Groundwater Flux
- E3 Groundwater Loading
- E4 Surface Water Loading
- E5 Total Loading

F DETAILED CALCULATIONS FOR THE CNR VICTORIA AVENUE LANDFILL, NIAGARA FALLS
- F1 Contaminant Concentrations
- F2 Groundwater Flux
- F3 Groundwater Loading
- F4 Surface Water Loading
- F5 Total Loading

G LIST OF U.S. EPA PRIORITY POLLUTANTS
LIST OF 14 CHEMICALS OF CONCERN

TABLE OF CONTENTS (continued)

Page #

TABLES

5-1 Summary of the Loading Calculations for the Atlas Steel Landfill, Welland 5-7

5-2 Certainty of the Loading Calculations for the Atlas Steel Landfill, Welland 5-8

5-3 Summary of the Loading Calculations for the Cyanamid Landfill, Welland 5-15

5-4 Certainty of the Loading Calculations for the Cyanamid Inc. Landfill, Welland 5-17

5-5 Summary of the Loading Calculations for the Cyanamid Cyanamid Inc. Landfills, Niagara Falls 5-24

5-6 Certainty of the Loading Calculations for the Cyanamid Inc. Landfills, Niagara Falls 5-26

5-7 Summary of the Loading Calculations for the Bridge Street Landfill, Fort Erie 5-32

5-8 Certainty of the Loading Calculations for the Bridge Street Landfill, Fort Erie 5-33

5-9 Summary of the Loading Calculations for the CNR Victoria Avenue Landfill, Niagara Falls 5-39

5-10 Certainty of the Loading Calculations for the CNR CNR Victoria Avenue Landfill, Niagara Falls 5-40

6-1 Summary of Loadings Estimates for the Canadian Hazardous Waste Sites 6-2

FIGURES

2-1 Locations of the 17 Canadian Hazardous Waste Sites 2-2

5-1 Location Map, Atlas Steel Landfill, Welland 5-3

5-2 Borehole and Surface Water Monitoring Locations, Atlas Steel Landfill, Welland 5-4

TABLE OF CONTENTS (continued)

		Page #
5-3	Location Map, Cyanamid Inc. Landfill, Welland	5-10
5-4	Borehole and Surface Water Monitoring Locations, Cyanamid Inc. Landfill, Welland	5-12
5-5	Location Map, Cyanamid Inc. Landfills, Niagara Falls	5-19
5-6	Borehole and Surface Water Monitoring Locations, Cyanamid Inc. Landfills, Niagara Falls	5-21
5-7	Location Map, Bridge Street Landfill, Fort Erie	5-28
5-8	Borehole and Surface Water Monitoring Locations, Bridge Street Landfill, Fort Erie	5-30
5-9	Site Location Map, CNR Victoria Avenue Landfill, Niagara Falls	5-37
5-10	Borehole and Surface Water Monitoring Locations, CNR Victoria Avenue Landfill, Niagara Falls	5-38

PART 1

INTRODUCTION

1.1 BACKGROUND

Concern about contaminant loadings to the Niagara River from both point and non-point sources in Canada and the U.S.A. has been raised since the late 1970's. The point source contributors, mainly sewers, have already been identified, and work has been undertaken to reduce sewer discharges to the river. Non-point sources, such as landfills, however, have been difficult to identify and quantify.

An initial non-point source investigation on the U.S. side of the Niagara River by Gradient Corp. and Geotrans Inc. in 1988 examined 70 individual waste disposal sites. Some of these consisted of clusters of individual sites, which reduced the total to 33 site areas. The site selection process was based upon criteria which were designed to include those sites which present the greatest potential for chemical loadings to the Niagara River.

Monenco Consultants Limited was awarded a contract by the MOE to use the same methodology to evaluate the potential loadings of five (5) waste disposal sites on the Canadian side of the Niagara River. Twelve (12) other sites assessed by the Ontario Ministry of the Environment (MOE) for the Niagara River Toxics Committee (NRTC, 1984) were determined to be non-significant contaminant sources. The sites selected by the MOE for inclusion in the NRTC report were:

- Atlas Steel Landfill, Welland
- Cyanamid Inc. Landfill, Welland
- Cyanamid Inc. Landfills, Niagara Falls
- Bridge Street Municipal Landfill, Fort Erie
- CN Rail Victoria Avenue Landfill, Niagara Falls

These sites were designated by the NRTC as "potential significant sources of contaminants" (NRTC, 1984).

1.2 TERMS OF REFERENCE

The Terms of Reference developed by the MOE required an analysis of potential loadings to the Niagara River from Canadian-based landfills as summarized below:

1) The consultant shall conduct a Phase II study involving an analysis of potential loadings to the Niagara River from Canadian-based landfills. The analysis should be done on the five sites identified in the 1984 Report of the Niagara River Toxics Committee:

   - Atlas Steel Landfill, Welland
   - Cyanamid Inc. Landfill, Welland
   - Cyanamid Inc. Landfills, Niagara Falls
   - Bridge Street Landfill, Fort Erie
   - CNR Victoria Avenue Landfill, Niagara Falls

2) The results of task 1) shall be presented in a report based upon the methodology used in the Gradient/Geotrans report and any deficiencies in either the database or the methodology shall be identified and the effect of the deficiency explained.

3) If deficiencies are identified in the database used in 1) above, the consultant shall, in a separate document to the Ministry, present recommendations to correct these deficiencies.

In addition, the MOE requested that Monenco identify, where possible, the loading of the fourteen (14) chemicals of concern identified for 50% reduction in the Niagara River Toxics Management Plan (NRTMP, 1979).

1.3 MONENCO APPROACH

Monenco Consultants Limited used the same approach that Gradient Corp. and Geotrans Inc. used in their 1988 report to estimate the potential loading (concentration multiplied by flux) from each site to the Niagara River. This involved an estimation of contaminant concentrations at the downgradient site boundaries based on available chemical analyses and the estimation of groundwater flux in all hydrostratigraphic units identified at each site. Unlike Gradient and Geotrans, Monenco also calculated the contribution from these sites of surface water discharges to the Niagara River.

Contaminant concentrations for each of the five (5) significant sites were based on the sum of the US Environmental Protection Agency (EPA) priority pollutants detected on each of the sites. This excluded chemicals found naturally at high concentrations, such as calcium, magnesium, sodium and iron. Contaminant concentrations in surface waters were determined for sites where surface water discharges were thought to be a significant component of the total loadings to the Niagara River.

Groundwater flow rates were determined using Darcy's Law and/or water budget calculations. Some of the surface water flow rates were obtained from data on file with the MOE. Loadings were then calculated by multiplying the contaminant concentrations by the flow rates. For all sites where sufficient data were available, potential loadings were determined from "high", "best" and "low" estimates of both contaminant concentrations and groundwater flow rates. On some sites, only "best" estimates could be made. This was the same approach used by Gradient Corp. and Geotrans Inc.

1.4 PROBLEMS OF APPROACH

There are several complications associated with the methodology used which are applicable to loading calculations for both sides of the Niagara River. The groundwater and soil data were collected by consultants, industry and government, and analysed by several different laboratories for different parameters, with varying detection limits. Sampling protocols, standards, and reliability also varied from lab to lab and site to site. These problems are difficult to rectify because of the number of sites involved. The only reasonable alternative would have been to have a government agency initiate a set of protocols for groundwater and soil monitoring, in order to ensure some consistency in data collection.

Another problem relates to the availability of data. Due to confidentiality restrictions, not all of the pertinent data were released to Monenco for inclusion in the calculations. Some studies are currently in progress and therefore not all of the most recent data were available. The problem of continually updated data will always exist. It is hoped that more data will clarify or improve the confidence in the data rather than create radical changes.

Another factor is the effect of biodegradation, chemical change, and volatilization with time and distance from the source of certain contaminants such as cyanide. As per the methodology of the Gradient/Geotrans report, these complications were ignored. It is likely, however, that most of the cyanide loadings calculated in this report do not reach the Niagara River due to natural degradation into nitrogenous compounds. Further details are provided in section 5.3.5.

The problems mentioned above could result in both determinate and indeterminate errors. Determinate errors are the result of identifiable biases. These errors are cumulative, and therefore increase in magnitude as the statistical sample size increases.

Indeterminate errors, such as analytical errors, are random, and tend to cancel out with larger sample sizes. It is the determinate errors therefore, which should be eliminated first.

PART 2

SITE ELIMINATION CRITERIA

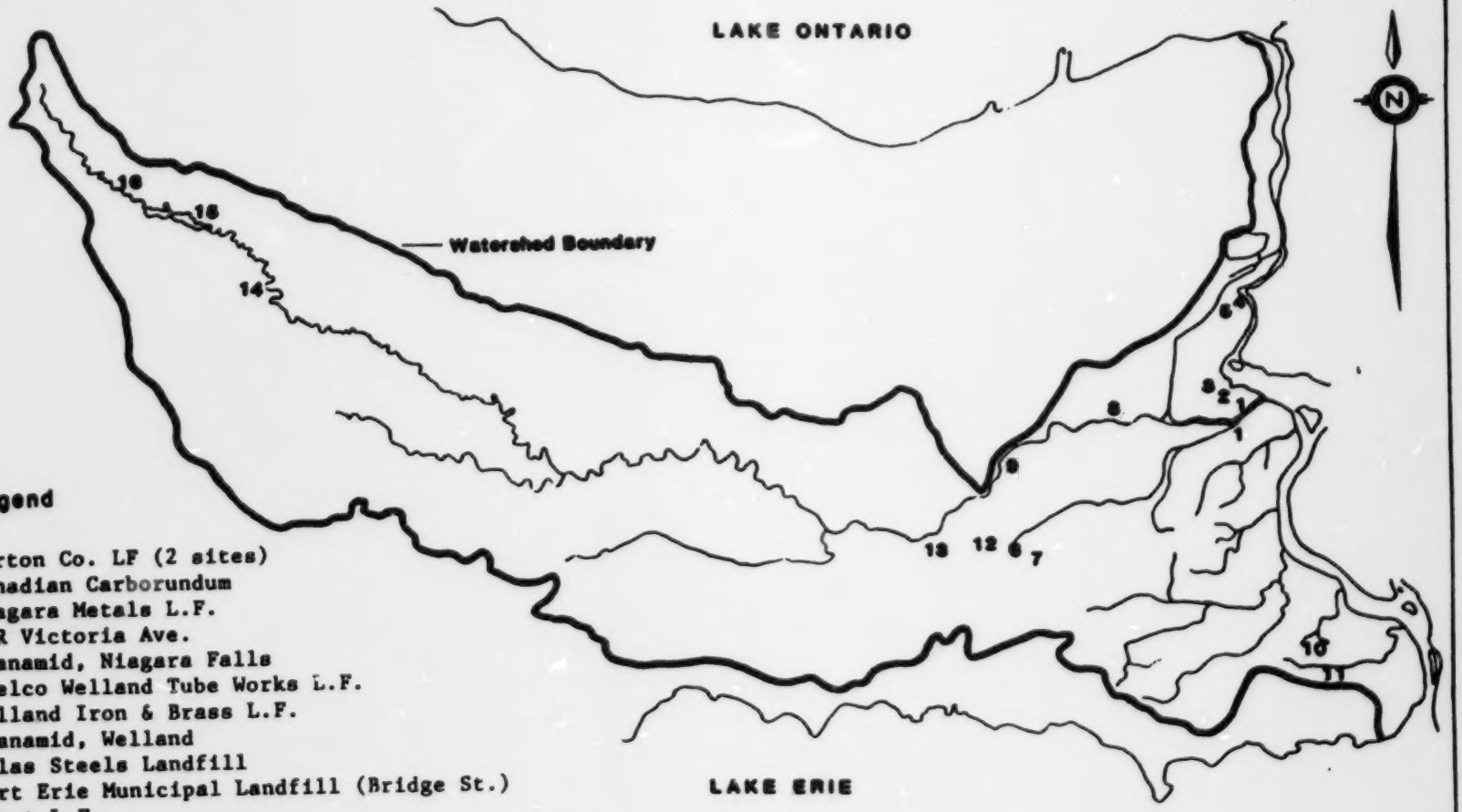
2.1 SITE SELECTION

This report considers five (5) sites within the drainage basin of the Niagara River that may have significant potential for contaminant migration. These sites were initially identified by the MOE for the NRTC, and were selected from a list of 17 known waste disposal sites within the Niagara River drainage basin (Figure 2-1).

Twelve (12) sites from the list of 17 were eliminated because the wastes were deemed by the MOE to be non-hazardous, or because contaminant migration through either surface or groundwater was deemed to be unlikely. Most of these sites are historical township dumps or small industrial landfills. A brief discussion of the 12 sites is provided in Appendix A. Omitting these landfills should not result in serious errors, since the available data indicate that neither surface water or groundwater impacts have occurred from any of the twelve sites. Chemical analyses for these sites included all parameters which would be expected to be present based upon the disposal history of the site, or contaminants that are known to be present at a particular landfill.

The five (5) sites selected for loadings calculations include the Atlas Steel Landfill in Welland, the Cyanamid Inc. landfills in Niagara Falls and Welland, the Bridge Street Landfill in Fort Erie, and the CNR Victoria Avenue Landfill in Niagara Falls. Surface and/or groundwater impacts from these landfills had been previously documented by either independent consultants or the MOE. A list of all of the reports used to formulate the loadings estimates on these sites is provided in Section 8.

Monenco



Legend

1. Norton Co. LF (2 sites)
2. Canadian Carborundum
3. Niagara Metals L.F.
4. CNR Victoria Ave.
5. Cyanamid, Niagara Falls
6. Stelco Welland Tube Works L.F.
7. Welland Iron & Brass L.F.
8. Cyanamid, Welland
9. Atlas Steels Landfill
10. Fort Erie Municipal Landfill (Bridge St.)
11. Fleet L.F.
12. Stelco Page-Hershey Works L.F.
13. Welland Municipal L.F.
14. Glanbrook Regional Landfill
15. Binbrook Landfill
16. Glanford-Mt. Hope L.F.

0 5 10 km
SCALE

Source: ODOM, 1984

NIAGARA - WELLAND DRAINAGE BASIN

ONTARIO NON-POINT SOURCES

FIGURE 2-1

MOE 8563-8

PART 3

CONTAMINANT LOADING CALCULATION METHODOLOGY

3.1 INTRODUCTION

Monenco Consultants Limited used the same methodology as Gradient Corp. and Geotrans Inc. The method involves estimating contaminant loadings (L) by multiplying the average contaminant concentration (C) by the groundwater flux (Q) through each of the hydrostratigraphic units. For this study, the calculated loadings were assumed to be unattenuated due to the proximity of all of the sites to the Niagara River, or its tributaries. This will most likely result in an overestimate of the contaminant concentrations, since biodegradation and attenuation will lower the levels of contamination reaching the Niagara River. The formula used to calculate the loadings was:

$$L = C \times Q,$$

where: L = loadings (kg/d)
C = concentration (mg/L - ppb)
Q = volume flux of groundwater (L/d)

The contaminant concentrations were estimated from the average of the individual analyses. The average concentration was calculated by averaging the sum of all US EPA Priority Pollutants (see list provided in Appendix G) found in the wells along the downgradient site boundary.

Total Organic Halogen (TOX) and Total Organic Carbon (TOC) analyses, were used along with a formula created by Gradient Corp. and Geotrans Inc. to calculate the concentration of organic contaminants in groundwater. These parameters are not usually analysed for in Canada, and therefore could not be used in this study. Instead, the sum of all organic contaminants detected on each of the sites was used. This may result in lower values of contaminant concentrations if one or more parameters are present but not analysed for on a particular site.

Further details on contaminant concentrations are provided in Section 3.2. Surface water loadings were also calculated for all applicable sites, whereas the Gradient and Geotrans study restricted the loadings calculations to the groundwater only.

Volume flux of groundwater was estimated from the Darcy Law and/or by water budget calculations. Details of each of these methods are provided in Section 3.3.

3.2 CONTAMINANT CONCENTRATION CALCULATIONS

3.2.1 Assumptions

For determination of contaminant concentrations it was assumed that all contaminants present were analysed for, and that all significant migration pathways were monitored.

3.2.2 Statistical Significance

Because of the very low values reported for the organic chemical concentrations, and the relatively few analyses, it is quite possible that the organic chemical concentrations may not be statistically significant relative to background levels. As well, the statistical distribution of chemical data is usually non-normal which makes determinations of central tendency difficult. In order to quantify this variability, high, low, and best estimates of the chemical concentrations were derived for most of the sites.

In order to make this study consistent with the investigation conducted by Gradient Corp. and Geotrans Inc., the average, or arithmetic mean of the contaminant concentrations across the downgradient boundary was used to represent the contaminant concentration from the site. Where nested wells were present, the nests were averaged together before being averaged with neighbouring

wells (Shifrin, 1989). This statistic is calculated as follows:

$$\bar{X} = \frac{X_1 + X_2 + X_3 + \ldots}{n}$$

where: $\bar{X}$ is the mean,
X_1, X_2, X_3 are contaminant concentrations
n is the number of analyses

3.3 GROUNDWATER FLUX CALCULATIONS

3.3.1 Assumptions

Any type of groundwater flux calculation based upon regional data collected from many sources is likely to be a gross estimate at best. Monenco used two of the approaches followed by Gradient Corp. and Geotrans Inc. in calculating the groundwater flux:

- Darcy's Law
- Water Budget

Darcy's Law is used in most hydrogeological studies, since it is one of the easiest methods to apply, and the results are considered to be of reasonable accuracy, given the inherent uncertainties involved in subsurface investigations. This method was used for calculating the groundwater volume flux in both overburden and bedrock.

Another common procedure for estimating volume flux is the water budget method which was used to determine the overburden volume flux estimate on one of the sites. Additional details on each of the methods are provided in the following text.

3.3.2 Darcy's Law

Darcy's Law can be stated as:

$Q = (K)(i)(A)$,

where:

Q = groundwater flux (m^3/s)
K = hydraulic conductivity (m/s)
i = groundwater gradient (m/m)
A = cross-sectional area perpendicular to the flow. (m^2)

Generally speaking, these estimates are accurate only to (+/-) 0.5 order-of-magnitude since "i" and "A" can be defined with reasonable accuracy, and "K" can only be measured to an accuracy of (+/-) 0.5 order-of-magnitude.

3.3.3 Water Budget

The Water Budget approach is calculated by the formula:

$P = R + I + ET +/- \Delta S$

where: P = Precipitation
R = Recharge
I = Infiltration
ET = Evapotranspiration
ΔS = Change in storage.

Recharge rates or infiltration, as estimated from long term precipitation records, and estimates of run-off and evapotranspiration, may exhibit less variation than the hydraulic conductivity, but these parameters were not measured. Since the values are assumed, as opposed to the measured "K" values, this estimation method may only be as accurate as Darcy's Law (i.e. $\pm$ 0.5 order of magnitude). The assumption is made that infiltration is uniform across the entire region. Since this area is covered by a variety of soil types, clay covers or impermeable pavement, this assumption is questionable. In addition, the assumed recharge values

cannot be applied to bedrock at depth where there is a significant flow-through from upgradient sources, unless the wastes are in contact with the bedrock groundwater. Since recharge rates are not easily determined, the same values used by Gradient Corp. were assumed by Monenco as follows:

low:	3 in/yr	- for waste/fill, alluvium, silt and sand
best:	9 in/yr	
high:	15 in/yr	
low:	1 in/yr	- for clayey silt and silty clay
best:	5 in/yr	
high:	9 in/yr	

These values are consistent with values used elsewhere in this area for rural properties. However, due to the amount of industry and regrading of the native soils, there is no guarantee that any site exhibits the assumed values because of the artificial reduction in infiltration. Underdraining of industrial areas could also result in an underestimation of loading. No testing was performed to verify that the assumed values are valid for this region. The error involved is determinate, but may not be cumulative, since some sites may be overestimated, while others may be underestimated.

3.3.4 Comparison of Methods for Estimation of Flux

The two methods used by Monenco have specific advantages and disadvantages. The parameters in Darcy's Law can be measured, but there is a fair degree of uncertainty in the determination of "K". Recharge rates in the Water Budget method involve parameters with less variation than Darcy's Law; however, they are assumed and not measured. For example, precipitation rates are well defined and run-off cannot exceed precipitation. Since Monenco allowed a range of values for infiltration between 1% and 50% of the precipitation rate for the region, the high and low estimates should span the true value.

3.4 SURFACE WATER LOADINGS

Surface water loadings were calculated for all sites except the Cyanamid Inc. landfill in Welland. To estimate this part of the total loadings, the observed flows were multiplied by the total contaminant concentration for each sampling event. The loadings were then averaged over the sampling period. This method assumes that the streams flow all year, and will be an overestimate of the actual loading if the streams are dry during the summer months. Only streams supplied primarily by overland flow were included, in order to prevent double counting of the shallow groundwater flow.

PART 4

DATA TREATMENT

4.1 CHEMICAL DATA

The most recent chemical data available were used to formulate the loadings estimate. The contaminants considered included the U.S. EPA Priority Pollutants (listed in Appendix G) which consists of both inorganic and organic compounds. A complete list is provided in Appendix G. Surface water concentrations were used to determine the total loadings to the Niagara River where concentrations and flow data were available (ie. total load = groundwater load + surface water load). All of the sites with the exception of the Atlas Steel Landfill in Welland did not have sufficient data for the estimation of background corrections.

The exact procedure for determining which wells were included in the groundwater concentration estimates depended upon site specific conditions. In general, with multiple well monitor nests, the "high" estimate was calculated as the average of the monitors with the highest contaminant concentrations at each of the nests. The "best" estimate was calculated as the average of all the monitors in each nest across the site boundary. The "low" estimate was determined using the "cleanest" well from each nest in the average.

The most recent monitoring data were used because contaminant concentrations appear to be relatively constant over time at each of the sites, and because these data are the most representative of current conditions. With some landfills, contamination occurred during the installation of some monitors, which is gradually decreasing. Therefore, contaminant concentrations may show some decreases over time.

Since groundwater data for these sites were relatively complete, only wells along the downgradient boundary at each of the five (5) sites were included in the analysis. This methodology is consistent with that used by Gradient Corp. and Geotrans Inc. Where multiple hydrogeological units were noted on the site and sufficient data

were available, the units were treated independently.

Common background constituents found in groundwater that are not on the EPA priority pollutant list (Appendix G) such as, calcium, magnesium, potassium, sodium, chloride, and sulphate were not calculated as part of the loadings determination. The exclusion of the background parameters allows a more realistic loading estimate to be made.

Contaminants that were detected on a site, but not in a particular well used for loadings computations were assigned concentrations equal to the detection limit. This may result in an overestimation of the contaminant concentration, but the methodology is consistent with that used by Gradient Corp. and Geotrans Inc.

4.2 HYDROGEOLOGICAL DATA

Hydrogeological information in the form of slug tests or approximations of hydraulic conductivities based on the grain size of the in-situ materials were available for all of the five sites. Wherever multiple hydrogeological units were present on the site, the flux rate was determined for each of the units separately. Arithmetic averages were computed as per Section 3.2.2.

4.3 CERTAINTY OF ESTIMATES

Due to the inherent problems in subsurface investigations, there is a large amount of uncertainty in the loading estimates. Groundwater flux rates are probably accurate to within an order of magnitude. Contaminant concentrations are somewhat more reliable, but it is possible that some other compounds were present for which analyses were not undertaken on some of the sites. With contaminants in surface waters, a large variation in chemical concentrations and flow rates causes a high degree of uncertainty in the resulting loadings estimate. The effects of buried conduits such as service

trenches are hard to predict. If present, they may result in a serious underestimation of contaminant concentrations and flow rates due to the traditional high permeability backfill materials used in these excavations.

PART 5

SITE ANALYSES

5.1 ATLAS STEEL LANDFILL, WELLAND

5.1.1 Background

The Atlas Steel Landfill was used from the early 1930's to the mid 1980's to dispose of electric furnace slag, baghouse dust, concrete and refractory rubble, and waste acids from the Atlas Steel plant in Welland, Ontario. This landfill is located in the City of Welland, adjacent to the Welland River, a tributary of the Niagara River. Since 1986, waste acids have been banned from the site and remedial acid has been removed for treatment. All other materials are still disposed of here.

The main contamination concern at this site is the leaching of heavy metals from the waste by residual acidic groundwater since the acidic source was removed. Surface water runoff flows over a weir directly into the Welland River and has been a concern in the past, but the installation of a holding pond has reduced this direct discharge to the Welland River. The location of the site is provided in Figure 5-1.

5.1.2 Hydrogeology

Hydrogeologic information for this site is limited to the overburden because of its low permeability and its 20 m thickness comprised of glaciolacustrine clays. Terraqua Investigations Limited conducted hydrogeologic investigations on the site for the MOE. Hydraulic conductivity testing was carried out on 19 wells, and water level data from 1984 and 1985 were presented in Terraqua's report entitled *Preliminary Hydrogeological Investigation of the Atlas Steels Landfill, Welland, Ontario*. A summary of the groundwater flux estimations derived from these data is provided in Table 5-1. The detailed calculations are shown in Appendix B2. Both the Darcy equation and recharge rates were used to estimate groundwater flux through the overburden, which ranges from 762 L/d to 10,666 L/d.

The groundwater flow direction according to the Terraqua data is westwards, toward the Welland River, with flow rates between 0.02 to 0.25 m/a suggested.

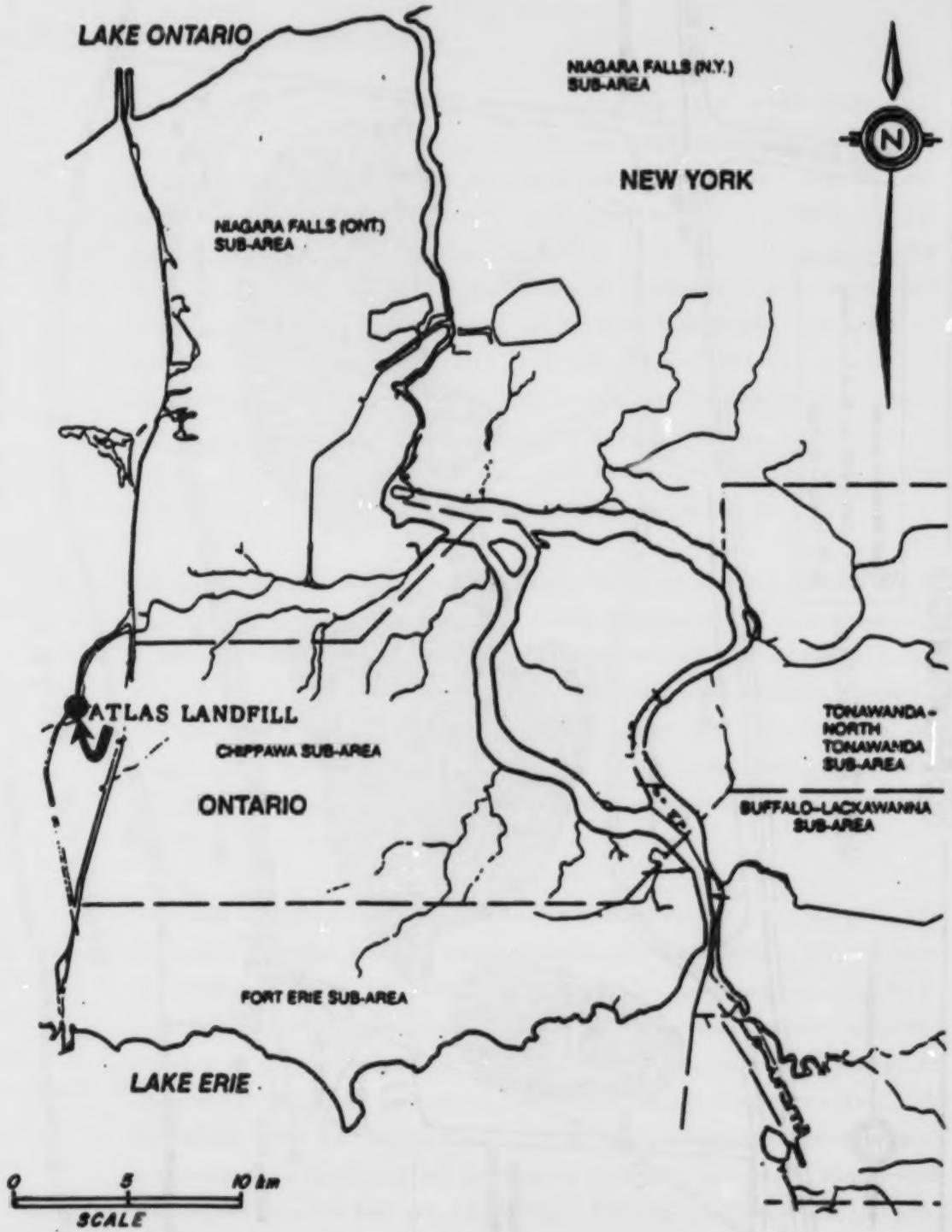
5.1.3 Available Monitoring Data

Eight (8) nests of monitoring wells with up to five (5) individual wells per nest were installed on the site (Figure 5-2). One well was installed to bedrock, a depth of (+/-) 22 m, while the others were installed to depths of less than 10 m. According to the Terraqua report prepared for the MOE, sampling was conducted in late 1984, and early 1985. A total of 22 samples were collected including five (5) from surface waters, and 17 from groundwater wells.

Constituents analyzed for were a variety of inorganic compounds, including heavy metals, nitrates, and cyanide. Some parameters (mercury, nitrates) were not analyzed for in every well. Neither Total Organic Carbon (TOC) nor Total Organic Halogen (TOX) were analyzed, and no individual organic compounds were analyzed.

A moderate amount of data from 1984 to 1986 were made available to Monenco for this site. The December 2-3, 1984 data were used to compute the loadings, since the other data did not include analyses from the groundwater wells. This should not result in serious errors, since the metal concentrations in the 1986 surface water data are very similar to the 1984 data. Analyses of surface water at the weir allowed direct measurements of the surface water discharges from the site. The sampling locations provided reasonable coverage of the site and included both upgradient and downgradient wells. The wells were nested, making it possible to estimate vertical, as well as horizontal gradients. No organic data were provided, but due to the nature of this landfill, organics were not expected to be a major concern.

Monenco



Source: TERRAQUA INVESTIGATIONS LTD., 1985

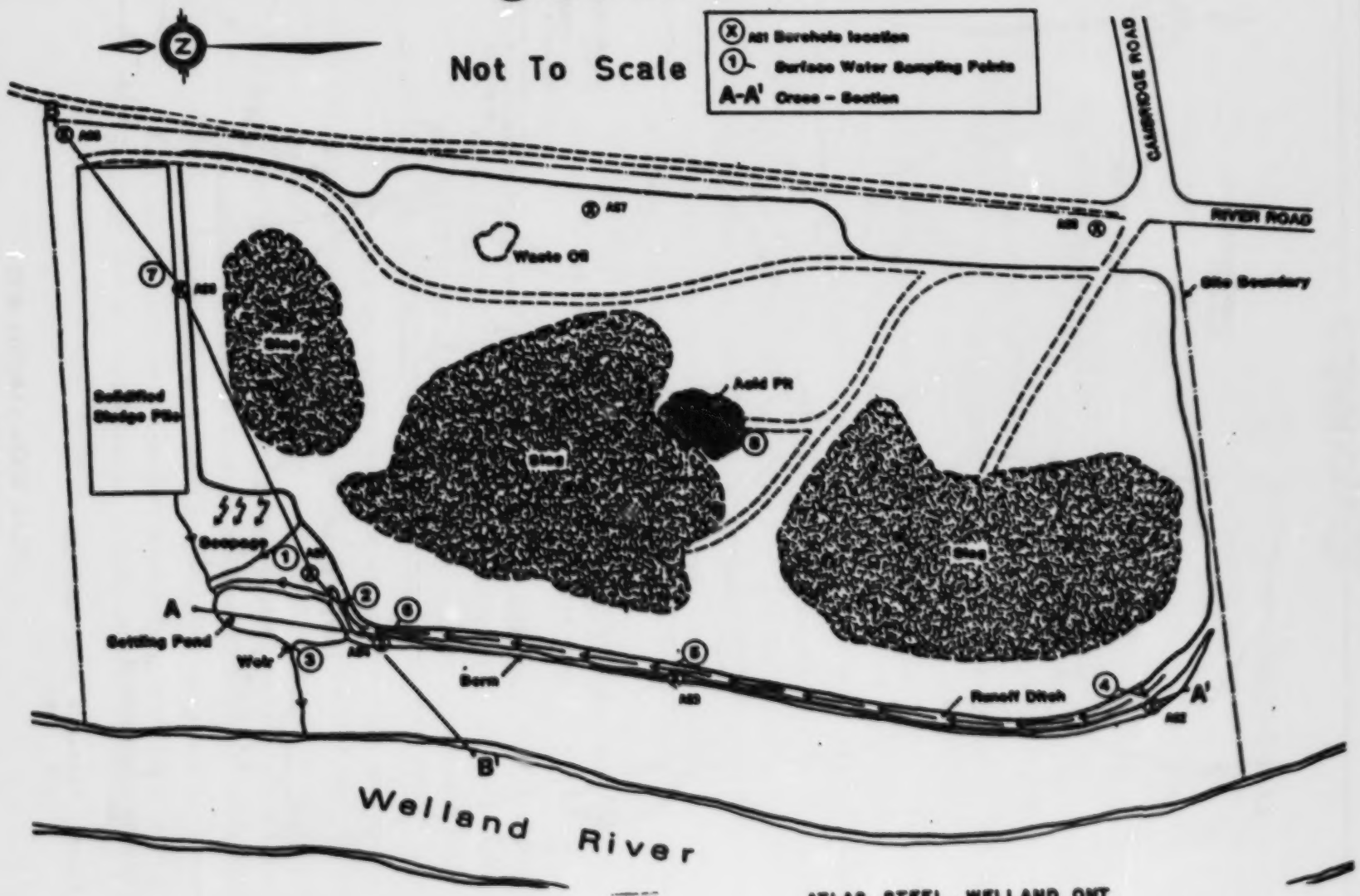
ATLAS STEEL LANDFILL SITE
WELLAND, ONT.

LOCATION MAP

MOE 8563-8

FIGURE 5-1

Monenco



ATLAS STEEL, WELLAND ONT.

MONITOR WELL AND SURFACE WATER SAMPLING LOCATIONS

FIGURE 5-2

Source: GARTNER LEE LTD. 1986

5.1.4 Contaminant Concentrations

An average contaminant concentration for the overburden was calculated for the downgradient (southern) site boundary, based upon the data from all of the wells installed on the site. Constituents with high natural (background) concentrations including calcium, magnesium, sodium, potassium, and iron were not included in the concentration calculations. Bedrock concentrations were not calculated, since no wells were installed in bedrock. The lack of bedrock data should not result in a significant underestimation of the contaminant concentration, since the overburden is both thick and highly impermeable, and would inhibit contaminant movement to depth. A summary of the chemical data is provided in Table 5-1, and the detailed calculations are provided in Appendix B1.

Estimated total non-natural inorganic compound concentrations range from 3,500 ppb to 64,000 ppb, with background levels of approximately 1,500 to 3,000 ppb. Strontium, manganese and aluminum are the primary contributors to these concentrations. No organic compound analyses were undertaken at the site, since the main concern was leaching of heavy metals. No values below detection limits were noted in the analyses, therefore they did not have any effect on the averages used herein.

The best estimate of the contaminant concentration (20,500 ppb) was calculated as the average concentration of trace metals in the most contaminated wells in each nest across the downgradient boundary. A background correction based upon the total "contamination" observed in well AS-8 (not including nitrates, which are anomalously high in this well) was used to adjust the downgradient concentration. To calculate the low estimate (15,900 ppb), the average chemical concentration from each of the boundary nests was used, along with the correction for background levels. The high estimate (22,100 ppb) was calculated by using the most contaminated well from each of the nests along the downgradient boundary without any background correction.

5.1.5 Loading Estimate

The best, low, and high estimates of the chemical concentrations, flow rates, and loadings estimates are provided in Table 5-1. The details of the surface water loading calculations are presented in Appendix B4. The groundwater loading calculations are provided in Appendix B3. Estimates of the total loadings range from 0.9 kg/d to 1.4 kg/d, with a best estimate of 1.1 kg/d (See Apendix B5). Surface water loadings comprise 0.9 kg/d of the total. All of the estimates represent loadings of inorganic compounds.

All flows from this site were assumed to enter the Welland River directly. Non-detects were not significant nor is there evidence that Non-Aqueous-Phase-Liquids (NAPL) exist at this site. The overall certainty of this estimate is rated as medium. A summary of the certainty of the loadings estimate is provided in Table 5-2.

5.2 CYANAMID INC. LANDFILL, WELLAND

5.2.1 Background

The Welland Plant of Cyanamid Canada Inc. is situated along the town boundary of the City of Niagara Falls and the City of Welland in the Regional Municipality of Niagara, Ontario (Figure 5-3). It is on the north bank of the Welland River, located on the northwest corner of Garner Road and Chippawa Creek Road.

The main contaminant concerns at this site are cyanide and nitrogen based compounds such as ammonia and nitrates. Surface water sampling points were not established, but chemical data from ten (10) creekbed (baseflow) monitors were included in the analysis.

Table 5-1 Summary of the Loadings Calculations for the Atlas Steel Landfill, Welland, Ontario

	High	Best	Low
Groundwater Concentration (1) ("C" - ug/L - ppb)	22,100	20,500	15,900
Groundwater Flux (2) ("Q" - L/d)	21,051	10,666	762
Groundwater Loading ("L(GW)=C*Q" - kg/d)	0.5	0.2	0.01
Surface Water Loading (3) ("L(SW)"- kg/d)	0.5	0.5	0.5
Total Loading ("L(T)=L(GW)+L(SW)" - kg/d)	1.0	0.7	0.5

Notes:

1 The high concentration estimate was calculated as the average of the highest concentrations in each of the downgradient nests without a background correction. The best estimate was taken as the high estimate corrected for background concentrations. The low estimate was calculated using the average of the average concentrations in each of the downgradient nests with a correction for background levels.

2 The high flux estimate was determined using the water budget approach, with an infiltration rate of 15 cm/a. The best estimate was based on the water budget approach, with an infiltration rate of 7.6 cm/a. The low estimate was calculated using Darcy's Law.

3 The surface water loading was calculated for phenols, trace metals and organic compounds. The detailed calculations are provided in Appendix B4.

Table 5-2 Certainty of the Loadings Calculations for the Atlas Steel Landfill, Welland, Ontario

Category of Information	High	Medium	Low
Number of sampling points		X	
Representativeness of sampling points		X	
Representativeness of sampling times			X
Representativeness of parameters analysed		X	
Certainty of identification of parameters analysed	X		
Ability to account for other loadings, e.g. NAPL, sewers		X	
Ability to account for non-detects	X		
Quality of available hydrogeological data		X	
OVERALL CERTAINTY		X	

Notes:

- Non-Aqueous-Phase-Liquid (NAPL) could result from old waste oil pit.
- More wells and sampling for organic contaminants might improve the loadings estimate.

This site is composed of three (3) separately licensed disposal areas, as follows:

- a 3 ha site known as the West Dump, licensed to receive 0.9 T/d of 100% non-hazardous wastes including floor sweepings, fly ash, scrap fibre, drums, wood and filter material

- Brown Road Dump, licensed to receive 45,000 tonnes per year of 100% non-hazardous wastes such as lime, limestone, carbon, ash, calcium carbonate, calcium oxide, broken brick, rubble and coke dust

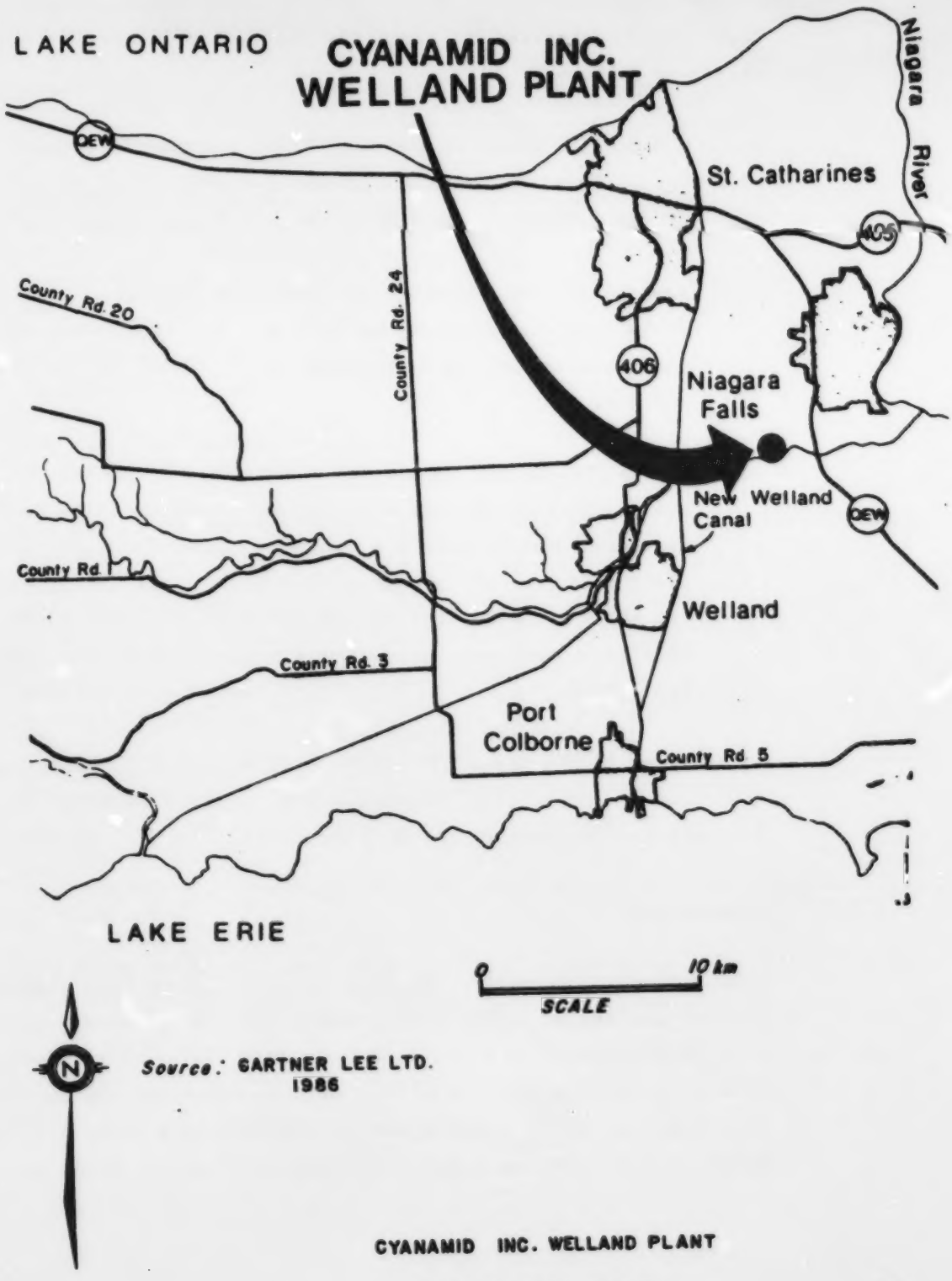
- eleven (11) bermed lagoons, 10 of which are now closed. Since 1942, each cell in turn has received a calcium oxide-calcium carbonate slurry from the dicyandiamide plant mixed with waste acid from the nitroguanidine plant since 1942. One of the cells was also used for the disposal of 32,000 tonnes of cyanide-contaminated solid waste material from the Niagara Falls Plant.

In addition to the three (3) sites mentioned above, mine tailings comprised of unidentified materials from previous workings on the site are present west of the West Dump site.

5.2.2 Hydrogeology

Hydrogeologic information for this site is relatively complete. Gartner Lee Limited (1985, 1986) reports that the "property consists of a thick sequence of stratified lacustrine clayey silts to depths of 9 to 15 m. The surface of this unit is weathered and fractured to a depth of about 3 to 5 m and is underlain by a sandy silt till which in turn overlies a dolomitic limestone aquifer found at

Monenco



CYANAMID INC. WELLAND PLANT

LOCATION MAP

MOE 8563-8

FIGURE 5-

depths of 15 to 20 m." Both laboratory and field measurements of hydraulic conductivity were made of the various hydrostratigraphic units identified on the site.

The Darcy equation was used to determine the groundwater flux in both the bedrock and overburden. Table 5-3 contains a summary of the detailed calculations, which are provided in Appendix C2. Flow through the overburden was estimated at 55 L/d to the Welland River and to Thompson's Creek, while bedrock flow to the Welland River was estimated at 2,601 L/d. Thompson's Creek does not receive groundwater flow from the bedrock.

5.2.3 Available Monitoring Data

Gartner Lee Limited installed 43 boreholes in 25 nests in 1984 and 1985. In addition, 10 mini-piezometers were installed within the bed of Thompson's Creek, and 31 shallow holes were augered to depths less than 1.5 m. The locations of these monitoring points are presented in Figure 5-4. Sampling was conducted in 1985 and 1986, but only data from 1985 were made available to Monenco due to Cyanamid confidentiality requests. Parameters analysed included: sodium, nitrate, nitrite, ammonia, Total Kjeldahl Nitrogen (TKN), fluoride, iron, cyanide and sulphate. No organic contaminants were included in the analyses provided to Monenco, nor was there any evidence of NAPL reported. In order for the results to be comparable to the Gradient/Geotrans Study, only the fluoride and total cyanide concentrations were used to formulate the loadings for this property.

A reasonably complete data set was available for this site. Only two sampling rounds were completed, but data for a large number of wells were collected. The sampling locations provided good geographical coverage of the site, and the selection of parameters

Monenco

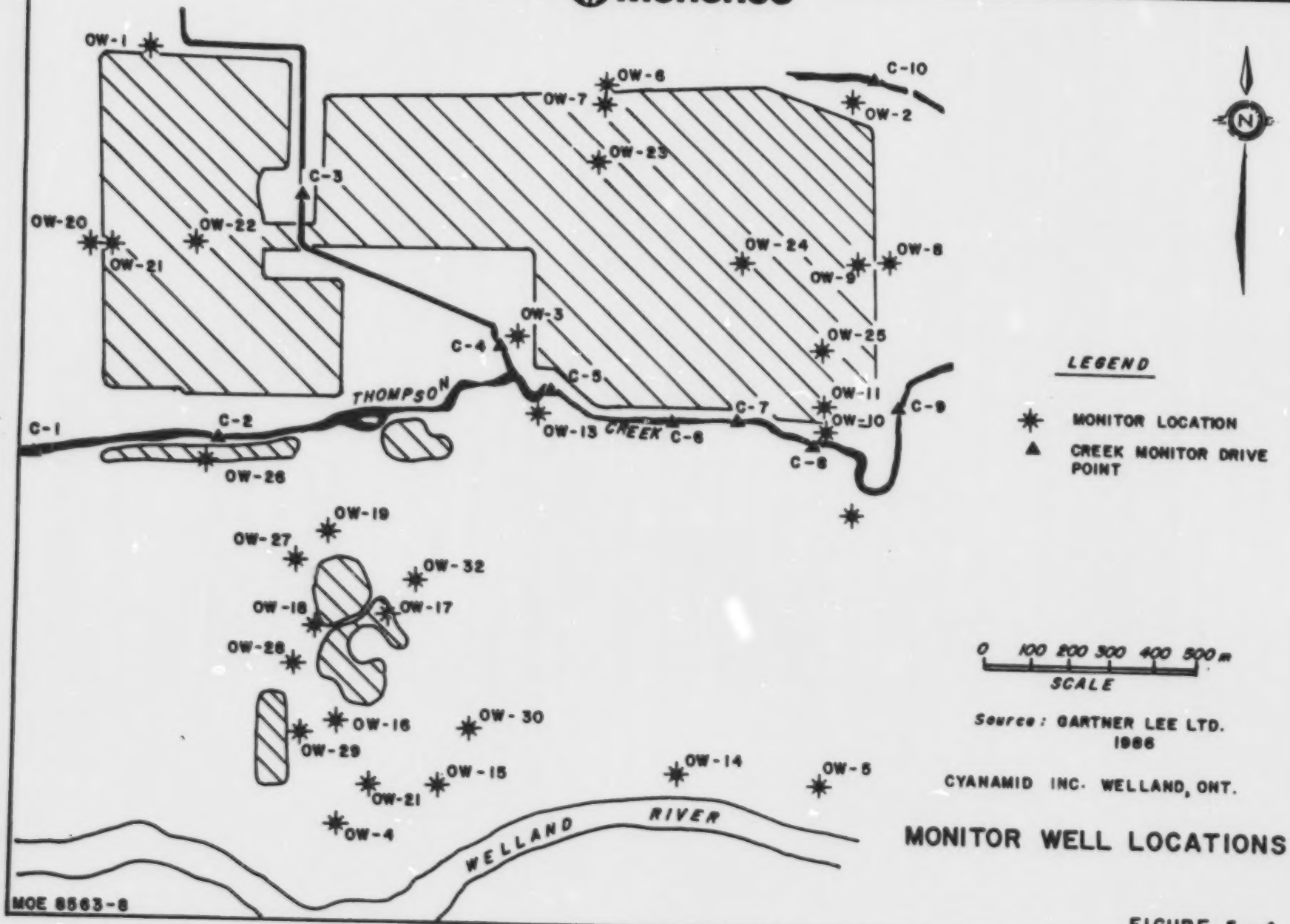


FIGURE 5-4

for analysis is well explained. The lack of organic contaminant data is not a serious problem, since organic contamination is not expected at this site.

5.2.4 Contaminant Concentration Calculations

Average contaminant concentrations were calculated for the downgradient (southern) boundary based on the analyses for total cyanide. A summary of the calculations is provided in Table 5-3, and the detailed calculations are given in Appendix C1. The concentrations in the bedrock ranged from 655 ppb to 1,707 ppb, with a best estimate of 1,296 ppb. In the overburden, best estimates were 2,801 ppb and 3,733 ppb to the Welland River and Thompson Creek, respectively.

5.2.5 Loading Estimate

The high, best, and low estimates of chemical concentrations, groundwater flux, and loadings estimates are provided in Table 5-3. Surface water loadings were not estimated for this site, because the creek bed minipiezometers account for the surface water loads. The estimates of groundwater loadings range from 0.001 to 0.03 kg/d, with a best estimate of 0.03 kg/d. All of the estimates represent inorganic compound loadings. The detailed calculations are provided in Appendix C3.

The concentrations based upon measured levels of cyanide were chosen as the best estimates. No data were available to assess the presence of organic contaminants. As the site history provides no indication that high levels of organics should be present, the omission of organic analyses should not compromise the quality of the loadings estimate.

Compounds reported below detection limits were not significant at this site, nor are there indications that additional discharge

sources, such as NAPL, are present. The overall certainty of the loading estimate is high. Including analyses for trace metals would increase the certainty of the estimates. A summary of the confidence in the data is provided in Table 5-4.

5.3 CYANAMID INC. LANDFILLS, NIAGARA FALLS

5.3.1 Background

Cyanamid Canada Inc. used lands around the Niagara Falls plant site, and lands leased from others, including Ontario Hydro, to dispose of cyanide bearing wastes during the construction of the Queenston-Chippawa Power Canal in the 1940's. In 1979, the wastes disposed on most of these sites were removed to ground level (totalling 32,000 tonnes). A report commissioned by the MOE estimated that some wastes have remained on the site in former natural depressions (MOE, 1985). A follow up study by Cyanamid estimated that 75,000 m^3 of process wastes and wasted raw materials existed on the site (Gartner Lee Limited, 1986). The originally identified landfill area is approximately 3 ha in size and is located between the Niagara River and the Chippawa Power Canal within the City of Niagara Falls (Figure 5-5). Since that time, investigations by Cyanamid have revealed a series of "satellite" disposal areas in the vicinity of Cyanamid's Fourth Avenue facility. The wastes are generally consistent among all of these sites.

Table 5-3: Summary of the Loading Calculations for the Cyanamid Inc. Landfills, Welland

	High	Best	Low
Contaminant Concentration (1) ("C" - ug/L - ppb)			
To Welland River			
Bedrock	(1)	1,296	(1)
Overburden	(1)	2,801	(1)
To Thompson Creek			
Overburden	(1)	3,733	(1)
Groundwater Flux (2) ("Q" - L/d)			
To Welland River			
Bedrock	7,415	2,601	389
Overburden	3,011	55	11
To Thompson Creek			
Overburden	3,011	55	11
Groundwater Loading ("L(GW)=C*Q" - kg/d)			
To Welland River			
Bedrock	9.61E-03	3.37E-03	5.04E-04
Overburden	8.43E-03	1.54E-04	3.08E-05
Total	1.80E-02	3.52E-03	5.35E-04
To Thompson Creek			
Overburden	1.12E-02	2.05E-04	4.11E-05
Total	0.029	0.004	0.004
Surface Water Loading (3) ("L(SW)" - kg/d)	N/A	N/A	N/A
Total Loading ("L(T)=L(GW)+L(SW)" - kg/d)	0.03	0.004	0.004

- Table continued -

Table 5-3. Continued

Notes:

E: Exponent

N/A: Not Applicable

1 Only a best estimate of the contaminant concentration was calculated, due to difficulty in locating a suitable background well (see Appendix C1 for details).

2 All groundwater flux estimates were based on calculations using Darcy's Law, with a range of values for the hydraulic conductivity. Details are provided in Appendix C2.

3 Surface water loadings were not calculated, since the creek bed minipiezometers account for these loadings.

Table 5-4 Certainty of the Loadings Calculations for the Cyanamid Inc. Landfill, Welland

Category of Information	High	Medium	Low
Number of sampling points		X	
Representativeness of sampling points		X	
Representativeness of sampling times		X	
Representativeness of parameters analysed		X	
Certainty of identification of parameters analysed		X	
Ability to account for other loadings, e.g. NAPL, sewers		X	
Ability to account for non-detects	X		
Quality of available hydrogeological data		X	
OVERALL CERTAINTY		X	

Note:

- Non-Aqueous-Phase-Liquid (NAPL) not expected on the site.
- Further sampling and including organic contaminants might improve the loadings estimate.

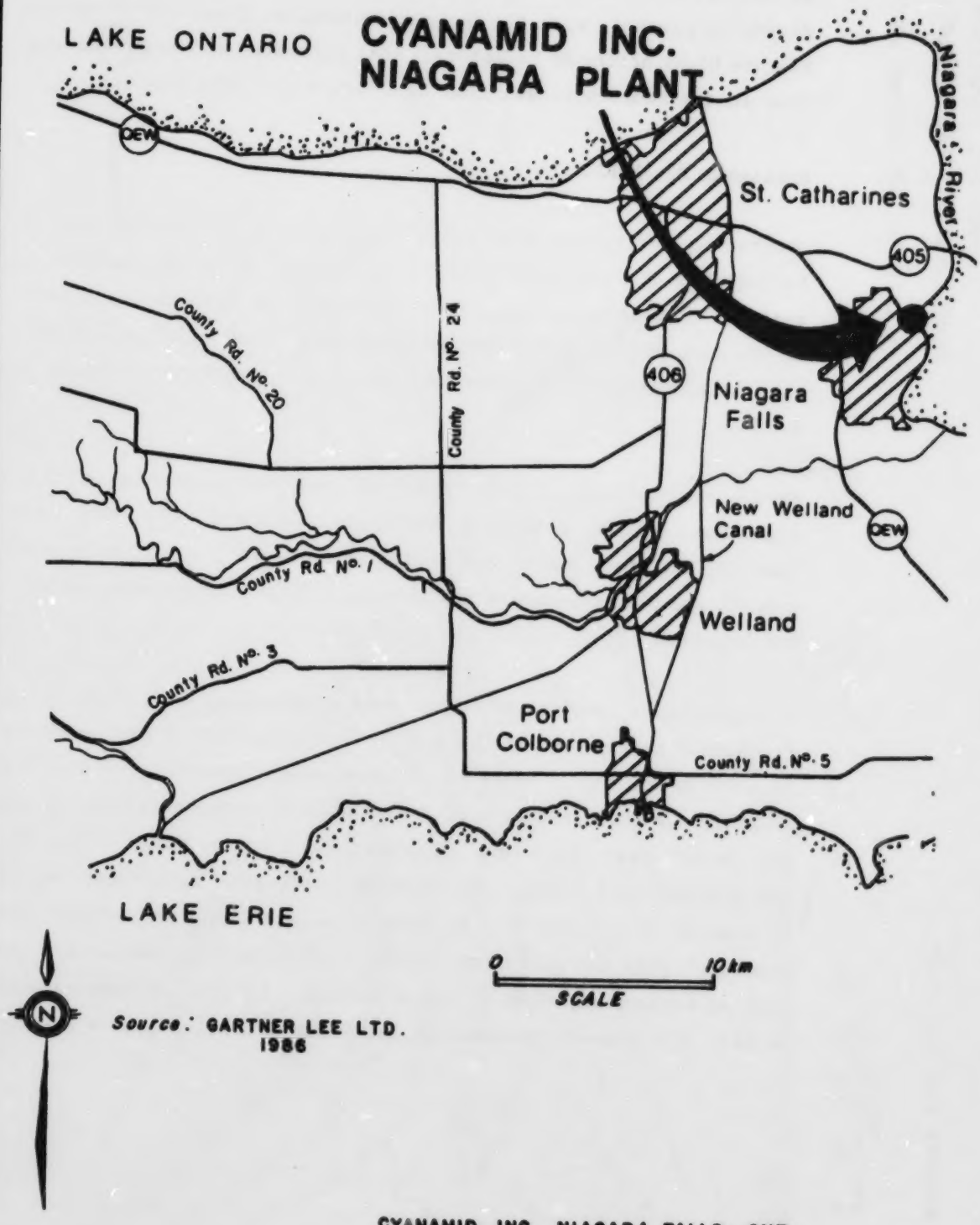
Surface water discharges to both the Niagara River and the Queenston-Chippawa Power Canal have been included in the loadings analysis. The main contaminant of concern is total cyanide. Nitrogen-based compounds such as ammonia have been analysed for, but are not included in the loadings computations. Only total cyanide is listed on the US EPA priority pollutants for which loadings were computed to be consistant with Gradient/Geotrans study on the US side.

Wastes disposed of at this site included lime, carbon, slaked lime, calcium carbide, ash, calcium carbonate, calcium oxide wastes, lining bricks, coal, coke, and limestone dust. The cyanide concentration in some of these wastes is significant (0.16% total cyanide, 0.03% free cyanide; MOE, 1985).

5.3.2 Hydrogeology

Hydrogeologic information is available for both the overburden and the bedrock. A summary of the groundwater flux estimations is provided in Table 5-5. Hydraulic conductivity testing was conducted on all of the monitors installed on the site. Water level data up to December 1988 were provided in a report by Gartner Lee Limited (1988).

Monenco



Source: GARTNER LEE LTD. 1986

CYANAMID INC. NIAGARA FALLS, ONT.

LOCATION MAP

MOE 8563-8

FIGURE 5-5

As was described in the Gartner Lee Limited report, a groundwater divide is present, with the Queenston-Chippawa Power Canal and the Niagara River acting as receptors. Best estimates of the groundwater flux in the bedrock ranges from 52,000 L/d to 2,805,000 L/d.

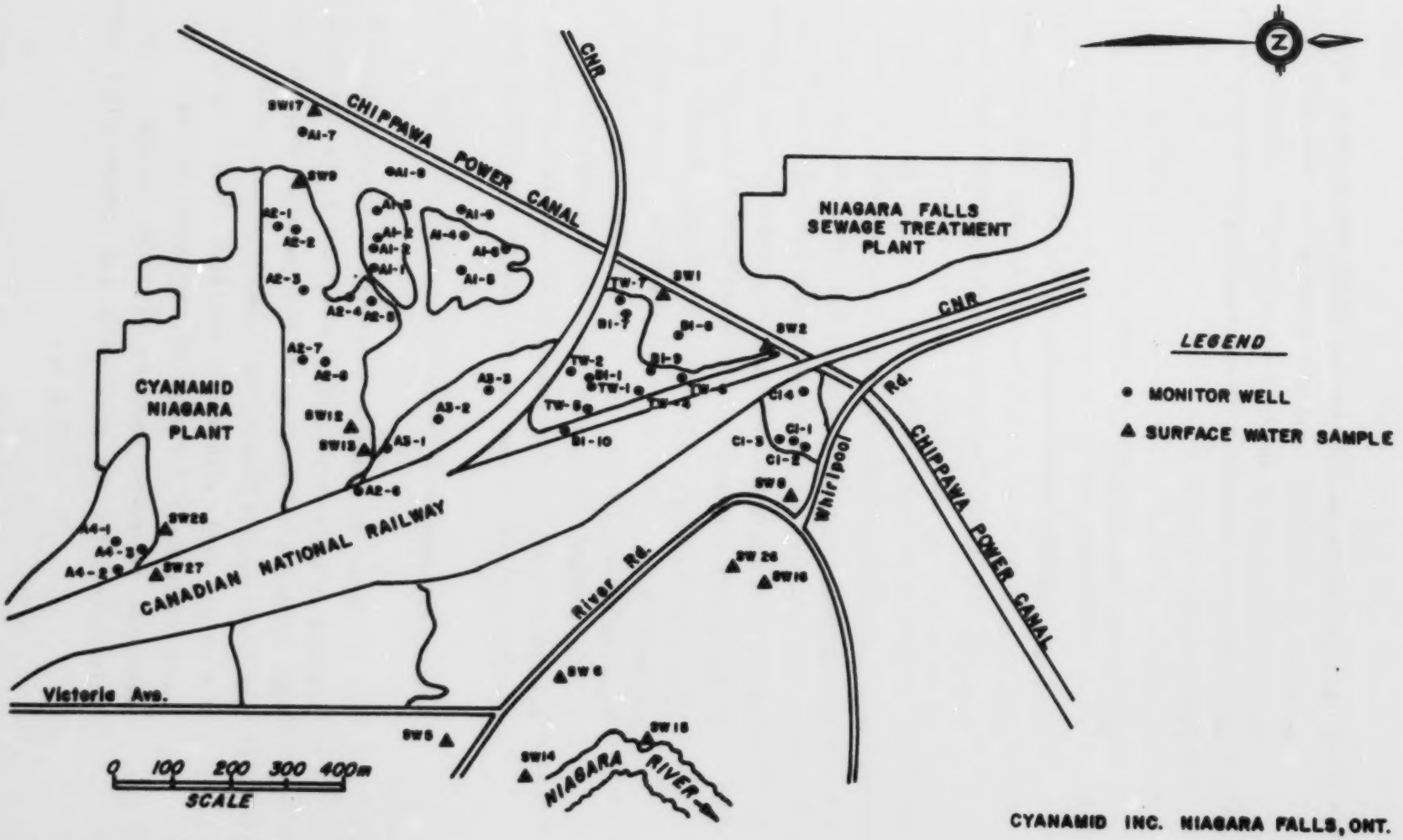
5.3.3 Available Monitoring Data

Monitoring wells have been established across the entire site by Gartner Lee Limited (1987,1988). A complete suite of analyses is available. Slug tests were performed in all the hydrogeologic units on the site and the subsurface stratigraphy is well defined. A site plan illustrating the monitoring locations is provided in Figure 5-6.

Parameters included in the chemical analyses included calcium, magnesium, sodium, potassium, chloride, sulphate, NO_2, NO_3, TKN, ammonia, DOC, and cyanide. As indicated in Section 5.3.1, only total cyanide was used to compute the loadings. Organic contaminants were not expected due to the nature of the wastes.

A significant amount of data were available for this site. Piezometer nests were installed at 39 locations with up to 4 monitors in each nest, for a total of 86 monitors. However, only a few monitors are representative of the contaminant concentrations at the site boundaries. Therefore, Monenco used the same wells as Gartner Lee Limited to determine the cyanide loadings. Background levels of cyanide were assumed to be zero by both Monenco and Gartner Lee Limited (1988) and therefore, background correction was made. The lack of background wells is not a serious problem, because natural levels of cyanide in groundwater are below detection limits and can

Monenco



Source: GARTNER LEE LTD. 1988

CYANAMID INC. NIAGARA FALLS, ONT.

MONITOR WELL AND SURFACE WATER SAMPLING LOCATIONS

MOE 8563-8

FIGURE 5-6

be assumed to be zero. Due to these constraints, only "best" estimates of the total cyanide concentrations were made. Surface water samples were collected from a total of 21 locations. The data were also recent, with 1988 data presented in the Gartner Lee Limited report (1988).

5.3.4 Contaminant Concentration Calculations

Average contaminant concentrations for the bedrock and the overburden were calculated at the downgradient site boundaries based upon wells along the boundaries. A summary of the chemical data is provided in Table 5-5, and the complete data set is given in Appendix D1.

For groundwater flowing to the Queenston-Chippawa Power Canal, cyanide concentrations average 13,550 ppb in the bedrock and 29,380 ppb in the overburden. For groundwater flowing to the Niagara River via the St. David's Buried Gorge, the cyanide concentration averages 24,900 ppb in the bedrock, and 50 ppb in the overburden. Direct loading to the Niagara River from groundwater averages 1,800 ppb in the bedrock and 75,600 ppb in the overburden. Very few values were reported below detection limits, and therefore were not significant in the overall contaminant concentration estimates. As stated earlier in Section 5.3.1, compounds of nitrogen, including ammonia, nitrate, and nitrite were not included in the loading computations.

5.3.5 Loading Estimate

The estimates of chemical concentrations, groundwater flux, and loadings estimates are provided in Table 5-5. Surface water loadings were estimated for drainage to the Queenston-Chippawa Power Canal and to the Niagara River. The estimates of total loadings range from 1.8 to 259 kg/d, with a best estimate of 26.9 kg/d. The surface water contributes 1.1 kg/d to the total loadings. All of the estimates represent loadings of total cyanide. The detailed calculations for the groundwater and surface water loadings are

provided in Appendices D3 and D4, respectively. Appendix D5 contains the calculations for the total loading.

It should be noted that the concentrations calculated in this study do not allow for natural attenuation and biodegradation of cyanide in order to be consistent with the Gradient/Geotrans methodology. As well, the overburden which contributes 20 kg/d of the total loading is not considered by other consultants to be a significant contributor. Given the data available to Monenco, however, contaminants are present in the overburden at the site boundary, and may be moving laterally, as well as vertically.

Limited data were available to assess the presence of organic and trace metal contaminants. However, as the site history provides no indication that high levels of either of these parameters should be present at the site. Therefore, omitting them should not seriously compromise the quality of the loadings estimate. There are also no indications that additional discharge sources, such as NAPL, are present.

Detection limits were not a significant factor at this site, since few compounds were noted as being below detection limits. The overall certainty of the loading estimate is high. A summary of the confidence in the data is provided in Table 5-6.

5.4 THE BRIDGE STREET LANDFILL, FORT ERIE

5.4.1 Background

The Bridge Street Landfill is located in Lot 7, Concession 4 in the former Township of Bertie, Regional Municipality of Niagara (Figure

Table 5-5 Summary of the Loadings Calculations for the Cyanamid Inc. Landfills, Niagara Falls

	High	Best	Low
Groundwater Contaminant Concentrations (1) ("C" - ug/L - ppb)			
To: Queenston-Chippawa Power Canal			
Bedrock	(1)	13,600	(1)
Overburden	(1)	29,400	(1)
To: Niagara R. via Buried Gorge			
Bedrock	(1)	24,900	(1)
Overburden	(1)	50	(1)
To: Niagara River Directly			
Bedrock	(1)	1,800	(1)
Overburden	(1)	75,600	(1)
Groundwater Flux (2) ("Q" - L/d)			
To: Queenston-Chippawa Power Canal			
Bedrock	1,866,240	268,800	24,883
Overburden	2,805,581	557,384	3,484
To: Niagara R. via Buried Gorge			
Bedrock	466,560	67,200	6,221
Overburden	127,526	52,255	1,742
To: Niagara River Directly			
Bedrock	466,560	67,200	3,600
Overburden	127,526	52,255	1,306

- Table continued -

Table 5-5 Continued

	High	Best	Low
Groundwater Loading ("L(GW)=C*Q" - kg/d)			
To: Queenston-Chippawa Power Canal			
Bedrock	25.4	3.7	0.3
Overburden	82.5	16.4	0.1
Total	107.9	20.0	0.4
To: Niagara R. via Buried Gorge			
Bedrock	11.6	1.7	0.2
Overburden	0.0	0.0	0.0
Total	11.6	1.7	0.2
To: Niagara River Directly			
Bedrock	0.8	0.1	0.0
Overburden	9.6	4.0	0.1
Total	10.5	4.1	0.1
Total	130.0	25.8	0.7
Surface Water Loading (3) ("L(SW)" - kg/d)			
To: Queenston-Chippawa Power Canal	0.7	0.7	0.7
To: Niagara River	0.4	0.4	0.4
Total Loading ("L(T)=L(GW)+L(SW)" - kg/d)			
To: Queenston-Chippawa Power Canal	108.6	20.7	1.1
To: Niagara R. via Buried Gorge	11.6	1.7	0.2
To: Niagara River Directly	10.9	4.5	1.5
Total	131.1	26.9	2.8

Notes:

1 Only best estimates of the chemical concentrations were made due to the lack of appropriate background wells (see Appendix D1).

2 Groundwater fluxes for both bedrock and overburden for all receptors were calculated using Darcy's Law with a range of values for the hydraulic conductivities, gradients, and saturated thicknesses (see Appendix D2 for details).

3 Surface water fluxes were determined for the two receivers based on flow data and chemistry provided by Gartner Lee Limited, 1988. Details are provided in Appendix D4.

Table 5-6 Certainty of the Loadings Calculations for the Cyanamid Inc. Landfills, Niagara Falls

Category of Information	High	Medium	Low
Number of sampling points	X		
Representativeness of sampling points		X	
Representativeness of sampling times	X		
Representativeness of parameters analysed		X	
Certainty of identification of parameters analysed	X		
Ability to account for other loadings, e.g. NAPL, sewers			X
Ability to account for non-detects	X		
Quality of available hydrogeological data	X		
OVERALL CERTAINTY	X		

Notes:

- Non-Aqueous-Phase-Liquid (NAPL) not expected on the site, but could be present.
- Sampling for organic contaminants might improve the loading estimate.

5-7). This site has been in use as a municipal landfill since 1972, and is still in operation. The site is reported to receive a total of 19,000 tonnes annually of residential (50%), commercial (30%), non-hazardous industrial (5%) waste, municipal sewage sludge (5%), and wood and construction waste (10%). The landfill currently occupies 12 ha in a total site area of 40 ha.

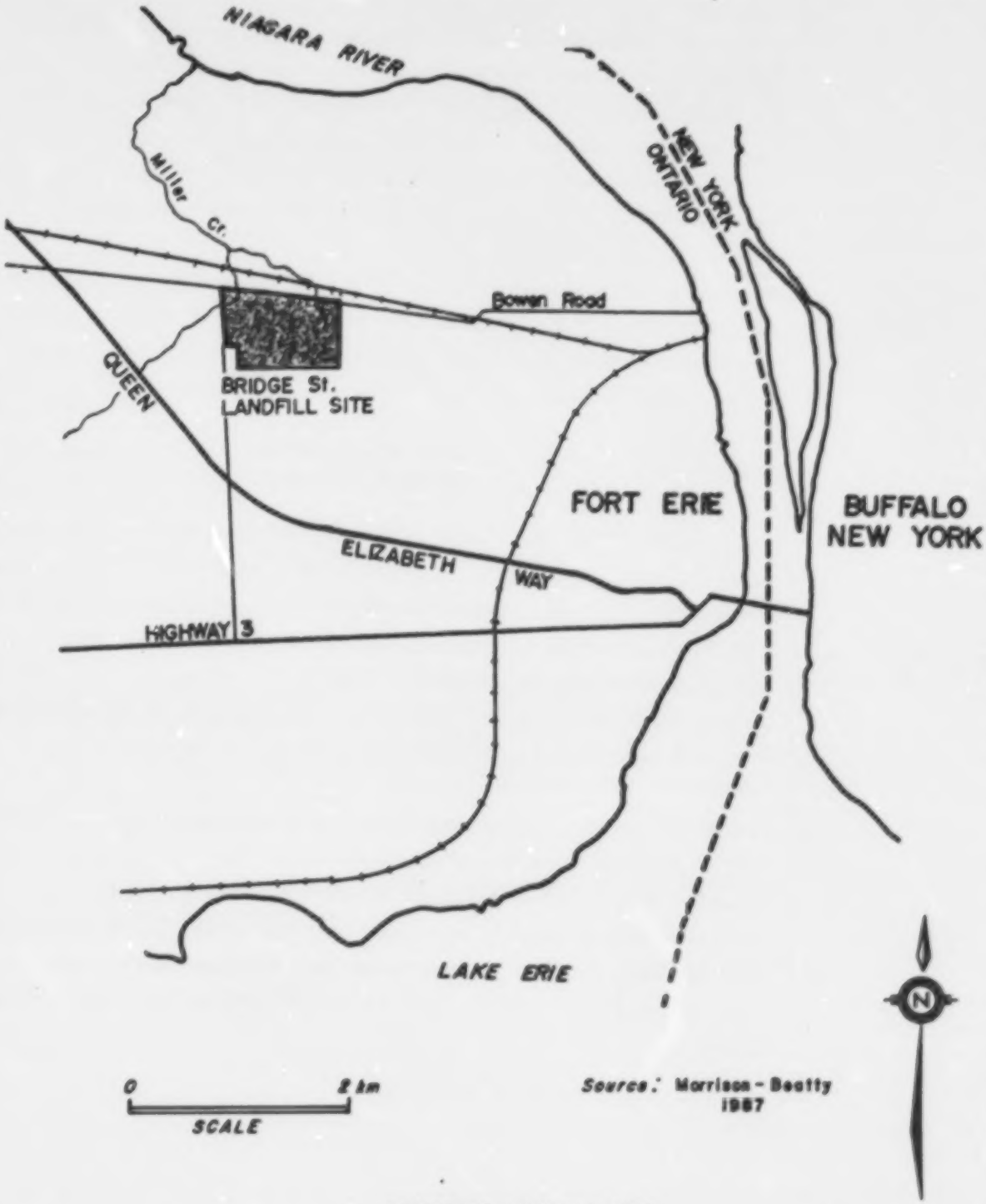
Surface water analyses from two (2) sampling points were included in the loadings calculations. The contaminants of concern included trace metals and organic compounds, as well as a full suite of conventional parameters.

5.4.2 Hydrogeology

This landfill is underlain by layers of glaciolacustrine clay, glaciofluvial sand, silt and clay, and silt till. The total overburden thickness ranges from 3 to 10 m. Morrison Beatty Ltd. completed 14 hydraulic conductivity tests on the weathered clay and the glacial/interglacial soils (1988a). Hydraulic conductivity values range from 4×10^{-9} m/s to 1×10^{-7} m/s, with an average of 4×10^{-8} m/s. Further details are provided in Appendix E2.

The water table data indicate that groundwater movement is towards the north, with a uniform gradient of 0.011. The average groundwater velocity calculated by Morrison Beatty Ltd. (1988a) is 0.5 m/a. The available potentiometric maps indicate that some of the overburden flux discharges to two small tributaries of Miller Creek on the north side of the site. Miller Creek is a tributary of the Niagara River proper.

Monenco



BRIDGE ST. LANDFILL SITE
FORT ERIE, ONT.

LOCATION MAP

MOE 8563-8

FIGURE 5-7

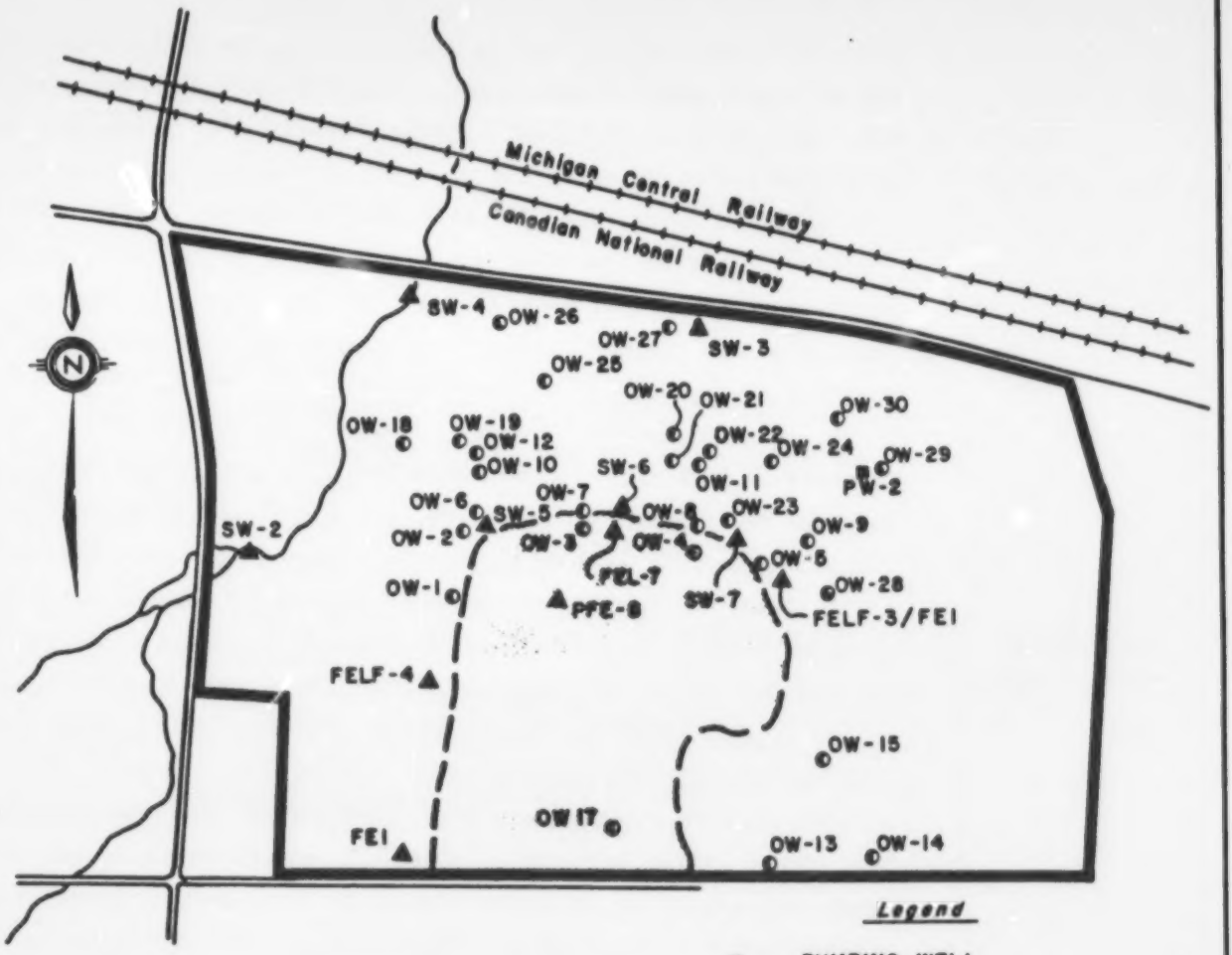
The bedrock beneath the area is identified as the Salina Formation. The east-west Onondaga Escarpment crosses through the centre of the site (Morrison Beatty Ltd., 1988a, 1988b). Groundwater flow gradients are steepest in the southern and eastern portions of the site (0.01 to 0.02), and virtually flat across the northern sector (<0.005). Most of the flow in the upper 4 m of bedrock, which is reported to be extensively fractured in some areas, is towards the Niagara River. However this flow appears to be impacted by the Onondaga Escarpment.

Groundwater flow rates in the bedrock could range from 10 to 100 m/a. Morrison Beatty Ltd. conducted two (2) pump tests in the northeast corner of the site, and calculated the hydraulic conductivity to be 6×10^{-4} m/s. According to the Morrison Beatty report, all of the groundwater flow in the bedrock is funnelled through a narrow (<50 m) corridor in the northeast corner of the site. However, due to the low gradients on the north side of the site it is possible that some of the groundwater may flow across the northern property boundary. In the groundwater flux calculations, summarized in Table 5-8, the flux was determined along the entire northern boundary, which may result in an overestimate of the loading. Additional groundwater potential information and analysis is required to further refine the loading estimate.

5.4.3 Available Monitoring Data

Thirty-four (34) nests of monitoring wells with up to four (4) individual wells per nest for a total of 78 monitors have been installed at this site (Figure 5-8). Groundwater sampling has been conducted since 1981, including analyses for routine chemisty, inorganics, metals and organics (bulk and selective). The data from 1988 were used for the loadings calculation since this sampling was the most recent and included most parameters. Data from 1984 and

Monenco



Source: MORRISON BEATTY LTD. 1987

BRIDGE STREET LANDFILL SITE
FORT ERIE, ONT.

MONITOR WELL AND SURFACE WATER SAMPLING LOCATIONS

MOE 8563-8

FIGURE 5-8

1986 were reviewed for some organic parameters which were not analysed in 1986. This review indicated that the loading calculations would not be biased by using the 1988 data.

A relatively complete data set is available for this site. An appropriate number of wells have been installed, with excellent coverage of the landfill area. Since some of the wells were nested, it is possible to estimate both vertical and horizontal gradients across the site. Several years of chemical data were available, which enabled a check on their long-term variability. Organic data are available including bulk parameters as well as volatile, extractable, purgeable, and landfill organics. Surface water sampling for organic and inorganic parameters has been performed by the MOE, which allows an estimation of the surface water loading from the site.

5.4.4 Contaminant Concentration Calculations

The contaminant concentration calculations are given in Appendix E1 and summarized in Table 5-7. The sum of the phenol and organic compounds contaminant concentrations average 3 ppb in the overburden and in the bedrock. Organic contaminant concentrations are below 10 ppb in all wells, and are usually less than 5 ppb. Wells within the waste are not included, since these wells would not provide an indication of which contaminants are leaching off the site.

5.4.5 Loading Estimate

The loadings calculations are summarized in Table 5-7. Details of the groundwater loadings are provided in Appendix E3. The surface water and total loading calculations are supplied in Appendices E4 and E5 respectively. The total loading is estimated to be 0.5 kg/d, virtually all of which is from surface water loading (0.49 kg/d). A summary of the confidence in the estimate is provided in Table 5-8.

Table 5-7 Summary of the Loadings Calculations for the Bridge Street Landfill, Fort Erie

	High	Best	Low
Groundwater Contaminant Concentrations (1) ("C" - ug/L - ppb)			
Bedrock	(1)	3	(1)
Weathered Clay	(1)	3	(1)
Glacial/Interglacial	(1)	3	(1)
Groundwater Flux (2) ("Q" - L/d)			
Bedrock	6,220,800	4,665,600	1,244,160
Weathered Clay	713	285	29
Glacial/Interglacial	21,384	5,702	14
Groundwater Loading ("L(GW)" - kg/d)			
Bedrock	0.0187	0.0140	0.0037
Weathered Clay	0.0000	0.0000	0.0000
Glacial/Interglacial	0.0001	0.0000	0.0000
Total	0.0187	0.0140	0.0037
Surface Water Loading (3) ("L(SW)"- kg/d)			
To: Niagara River	0.5	0.5	0.5
Total Loading ("L(T)=L(GW)+L(SW)" - kg/d)	0.5	0.5	0.5

Notes:

1 Only a best estimate of the contaminant concentration was calculated, due to difficulty in locating a suitable background well (see Appendix E1).

2 All groundwater flux estimates were based on calculations using Darcy's Law, with a range of values for the hydraulic conductivity (see Appendix E2).

3 Surface water fluxes were determined for the receiver based on flow data and chemistry provided by Morrison Beatty, 1989. Details are provided in Appendix D4.

Table 5-8 Certainty of the Loadings Calculations for the Bridge Street Landfill, Fort Erie, Ontario

Category of Information	High	Medium	Low
Number of sampling points	X		
Representativeness of sampling points		X	
Representativeness of sampling times		X	
Representativeness of parameters analysed		X	
Certainty of identification of parameters analysed	X		
Ability to account for other loadings, e.g. NAPL, sewers	X		
Ability to account for non-detects	X		
Quality of available hydrogeological data		X	
OVERALL CERTAINTY		X	

Notes:

- Non-Aqueous-Phase-Liquid (NAPL) not expected on the site.
- More wells and sampling for both organics and metals may improve the loadings estimate.

5.5 CNR VICTORIA AVENUE LANDFILL, NIAGARA FALLS

5.5.1 Background

The CN Rail Victoria Avenue Landfill is located near the west corner of Victoria Avenue and Niagara River Boulevard in Niagara Falls (Figure 5-9). The site has been used from the late 1960's until 1981 to dispose of car cleaning wastes at the Niagara Falls railyards. Such wastes included scrap metal and wood, foundry magnets, paper, lube pads, and some domestic waste. The site was covered with one 1 m of clay in 1981.

Surface water discharges from the site have been monitored by the MOE from 1982 to the present. Trace metals and nitrogen compounds were the primary contaminants of concern, since regular burning of the waste destroyed the organic fraction of the wastes (MOE, 1984).

5.5.2 Hydrogeology

Hydrogeologic information for this site is limited to the overburden. Hydrology Consultants Limited (1985) installed one monitoring well, and collected one groundwater sample. No hydraulic conductivity testing was carried out on the property; however, the data collected by Gartner Lee Limited for their investigation into the adjacent Cyanamid Inc. landfills in Niagara Falls can be applied to this site and were used to formulate a loadings estimate. The detailed calculations of the groundwater flux are shown in Appendix F2 and a summary is presented in Table 5-9. The groundwater flow direction, as described by Gartner Lee Limited (1988) is eastwards, toward the Niagara River, with rates between 0.02 to 0.25 m/a suggested.

The Darcy equation was used to estimate groundwater flux through the overburden, which ranged from 1,742 L/d to 127,526 L/d.

5.5.3 Available Monitoring Data

Data from one (1) bedrock test well installed by Hydrology Consultants (1985) are available for this site. Three (3) other test holes were drilled, but no other monitors were installed. Exact locations of any of these holes were not provided. Another borehole was drilled by Gartner Lee Limited (1988) adjacent to the northeast corner of the site for an investigation into the Cyanamid Inc. Landfills in Niagara Falls. The locations of these monitors are shown in Figure 5-10. Both organic and inorganic contaminants were analysed for in the test well, and in the surface water.

Monitoring consisted of single grab samplings in 1982 (surface water) and 1985 (test well) on the CNR site itself, while more recent and continuous data were available for the wells installed by Gartner Lee Limited on the adjacent Cyanamid property. Indicator parameters were not used on the site, since the sampling program consisted of only one sampling event.

5.5.4 Contaminant Concentration Calculations

Average concentrations of total inorganic and organic parameters were calculated for the overburden. Contaminant calculations are provided in Appendix F1. A summary of the high, best and low estimates is shown in Table 5-9.

The lack of bedrock data should not result in a significant underestimation of the contaminant concentration, since the overburden is both thick and relatively impermeable. Variations in the stratigraphy (till & sand layers) exist, but the overall thickness and low permeability of the overburden should prevent migration of contaminants to the bedrock.

The estimated total inorganic contaminant concentration is 7,401 ppb. Few non-detects were noted in the analyses, therefore they had

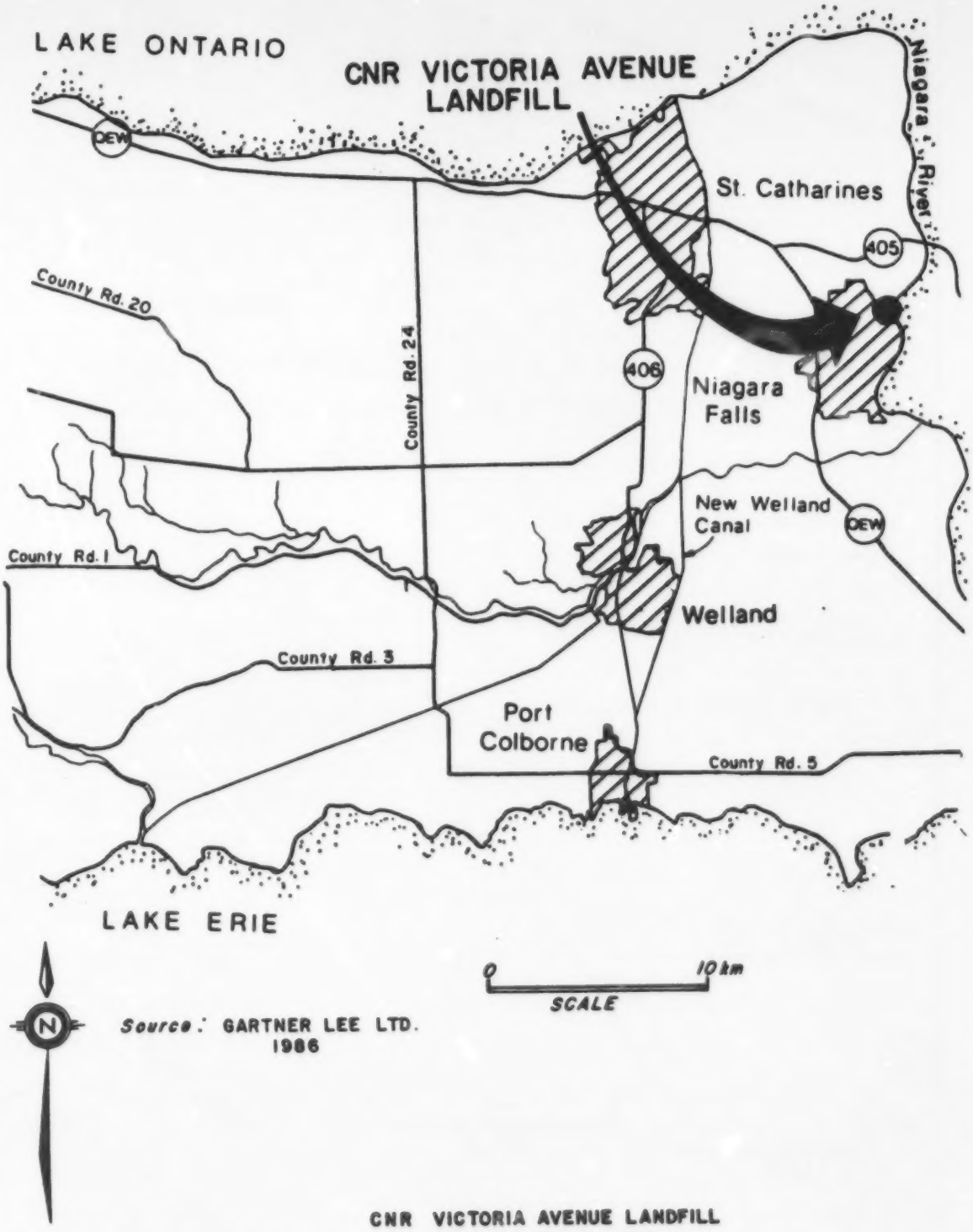
little effect on the computed averages. No background correction was possible, due to the absence of any other monitoring wells. The Gartner Lee Limited data (1988) are not useable for background calculations, since different parameters were analysed.

5.5.5 Loading Estimate

The best estimate of the chemical concentrations and the high, best, and low estimates of the flow rates and loadings estimates are provided in Table 5-9. The details of the surface water loading calculations are presented in Appendix F4. The groundwater and total loading calculations are provided in Appendices F3 and F5, respectively. Estimates of the total loadings range from 1.6 kg/d to 2.5 kg/d, with a best estimate of 2.0 kg/d. Of these values, 1.6 kg/d is due to surface water loadings. All of the estimates represent non-organic loadings (mostly metals).

Chemicals analysed for but found to be below detection limits were not significant on this site. There is no evidence that Non-Aqueous-Phase-Liquids (NAPL) exist at this site. The overall certainty of this estimate is rated at medium. A summary of the certainty of the loadings estimate is provided in Table 5-10.

Monenco



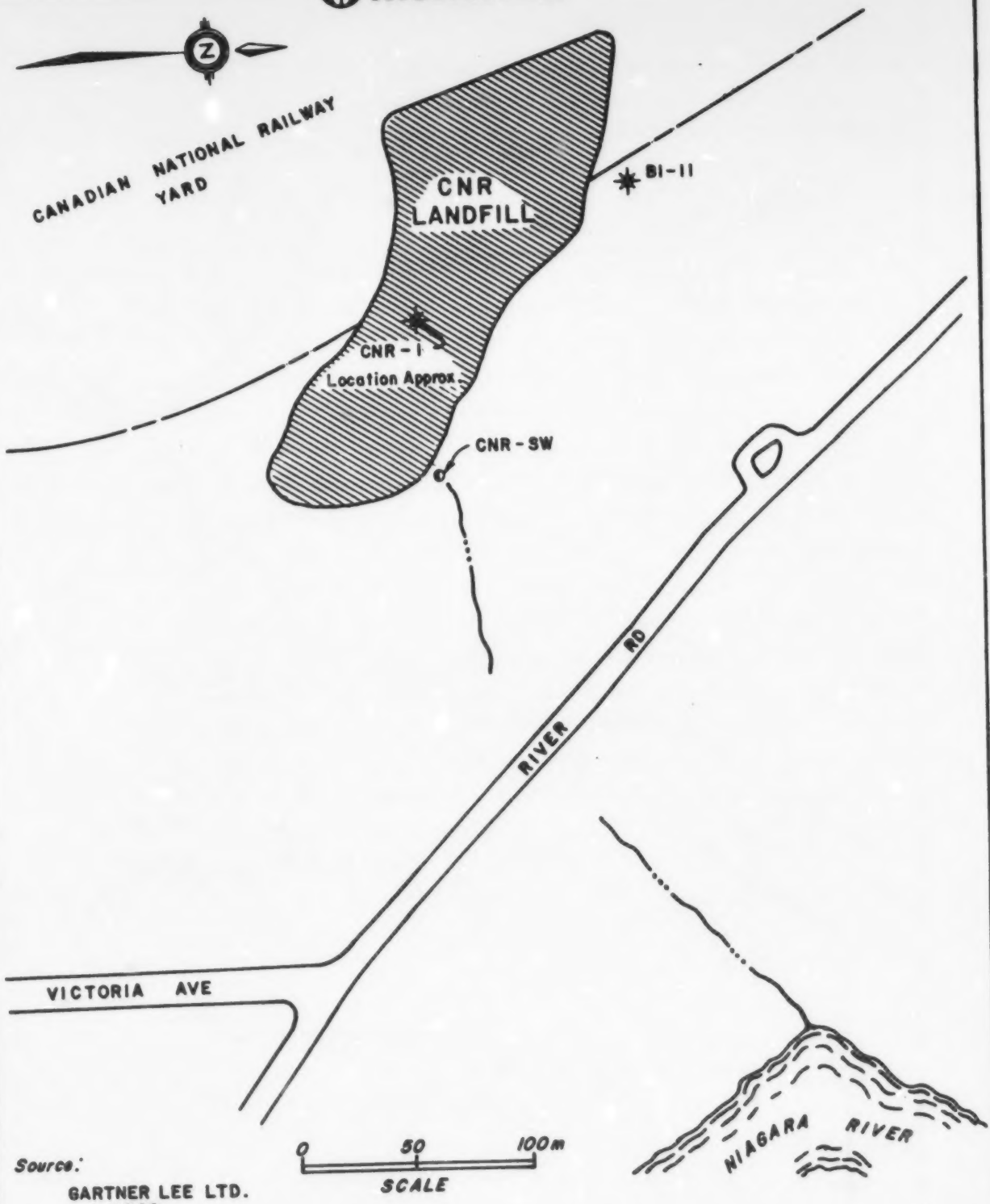
CNR VICTORIA AVENUE LANDFILL
NIAGARA FALLS, ONT.

LOCATION MAP

MOE 8563-8

FIGURE 5-9

Monenco



Source:
GARTNER LEE LTD.
1988

CNR LANDFILL NIAGARA FALLS, ONT.

MONITOR WELL AND SURFACE WATER SAMPLING LOCATIONS

FIGURE 5-10

MOE 8563-8

Table 5-9 Summary of the Loadings, Calculations for the CN Rail Victoria Avenue Landfill, Niagara Falls

	High	Best	Low
Contaminant Concentration (1) ("C" - ug/L - ppb)	(1)	7,401	(1)
Groundwater Flux (2) ("Q" - L/d)	127,526	52,255	1,306
Groundwater Loading ("L(GW)=C*Q" - kg/d)	0.94	0.39	0.01
Surface Water Loading (3) ("L(SW)" - kg/d)	1.6	1.6	1.6
Total Loading ("L(T)=L(GW)+L(SW)" - kg/d)	2.5	2.0	1.6

Notes:

1 Only a best estimate of the contaminant concentration was calculated, due to difficulty in locating a suitable background well (see Appendix F1 for details).

2 All groundwater flux estimates were based on calculations using Darcy's Law, with a range of values for the hydraulic conductivity. Details are provided in Appendix F2.

3 Surface water loadings were calculated based upon MOE sampling from 1982-1988 (see Appendix F4).

Table 5-10 Certainty of the Loadings Calculations for the CN Rail Victoria Avenue Landfill, Niagara Falls

Category of Information	High	Medium	Low
Number of sampling points			X
Representativeness of sampling points			X
Representativeness of sampling times			X
Representativeness of parameters analysed		X	
Certainty of identification of parameters analysed		X	
Ability to account for other loadings, e.g. NAPL, sewers			X
Ability to account for non-detects		X	
Quality of available hydrogeological data			X
OVERALL CERTAINTY			X

Notes:

- Non-Aqueous-Phase-Liquid (NAPL) not expected on the site, becau of regular burning of wastes at this site (see text for details
- More wells are needed at this site to properly determine the groundwater flow system. More sampling is also reqired.

PART 6
SUMMARY OF RESULTS

6.1 SUMMARY

Potential Contaminant loadings to the Niagara River from groundwater and surface water contributions at selected Canadian landfill sites are estimated to total 30.5 kg/d. This estimate is based upon concentrations of both organic and inorganic compounds. The organic component of the loading is approximately zero. The loading of the fourteen (14) Parameters of Concern (see Appendix G) is zero.

Of the total loading, 26.9 kg/d originates at the Cyanamid Inc. landfills at Niagara Falls. The CN Rail Victoria Avenue landfill in Niagara Falls is the next largest contributor (2 kg/d), followed by the Atlas Steel landfill, Welland (1.1 kg/d); Bridge Street landfill, Fort Erie (0.5 kg/d); and the Cyanamid Inc. landfill, Welland (0.004 kg/d). A summary chart is provided in Table 6-1.

The other 12 landfills in the Niagara River watershed which were not studied are believed not to be contributing any loading, based on the most recent data available.

When loadings for the five Canadian sites are compared to the 33 site areas evaluated by Gradient Corp. and Geotrans Inc., the comparable groundwater loading from the Ontario sites is 26.9 kg/d, which represents 10% of the magnitude of the total loading from US sites. The total loading values in this report include surface water loadings, which were not estimated by Gradient Corp. and Geotrans Inc.

Table 6-1 Summary of "Best" Loadings Estimates

Site	Groundwater Loading		Surface Water Loading (kg/d)	Total Loading (kg/d)
	Organic (kg/d)	Inorganic (kg/d)		
Cyanamid Inc. landfills, Niagara Falls	0	25.8	1.1	26.9
CN Rail landfill, Niagara Falls	0	0.4	1.6	2
Atlas Steel landfill, Welland	0	0.2	0.5	0.7
Bridge Street landfill, Fort Erie	0.01	0	0.5	0.51
Cyanamid Inc. landfill, Welland	0	0.004	N.A.	0.004
Total, 5 Canadian Sites	0.01	26.4	3.7	30.1
Total, 33 U.S. sites (Gradient/Geotrans)	179.1	38.2	N.D.	217.3

Notes:

- N.A. : Not Applicable
- N.D. : Not Determined

PART 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based upon Monenco's evaluation of the methodology and detailed calculations, the following conclusions may be made:

- some data gaps are present, due to problems of confidentiality, inconsistencies in field and laboratory methods, and lack of current data due to studies that were not complete at the time of publication this report. These insufficiencies are generally a lesser problem than those in the US data.

- The loadings calculated in this report include surface water inputs not considered by Gradient Corp. and Geotrans Inc. in their report on contaminant loadings from U.S. landfills.

- Total potential loadings from surface and groundwater contributions to the Niagara River of US EPA Priority Pollutants are 30.5 kg/d from the five (5) selected Canadian landfill sites

- The 12 Canadian landfills (Appendix A) which were not fully evaluated in this report, do not appear to be causing any loadings to the Niagara River, based upon the most recent data available

- Total potential loadings of the fourteen (14) Parameters of Concern are 0 kg/d from the five (5) selected Canadian landfill sites

- Unlike the U.S. landfills, organic contaminants are not a significant fraction of the total loading for the Canadian sites

- The landfills surrounding the Cyanamid Inc. plant in Niagara Falls are the primary contributors to the loading estimates

(26.9 kg/d)

- Fort Erie's CN Rail Victoria Avenue landfill is the second most serious concern, with a loading estimate of 2 kg/d.

- The other three (3) landfills contribute less than 2 kg/d each

7.2 RECOMMENDATIONS

Based upon the conclusions noted above, the following recommendations can be made:

- The most recent and complete data available should be used.

- Sampling and analytical protocols for all sites should be uniform and established by a government agency for both the Canadian and US sites; these protocols should address such issues as quality assurance (trip blanks, duplicate samples, spiked samples), as well as specifying desired detection limits and parameters for analysis

- New data should be collected using the above protocols, on the Cyanamid Inc. landfills in Niagara Falls, the CNR landfill in Niagara Falls the Bridge Street landfill in Fort Erie and the Atlas Steel Landfill in order to refine the loading estimates; these sites have significant loadings which need refinement through the inclusion of more recent or comprehensive data.

- Investigations should continue at the Cyanamid Inc. landfills in Niagara Falls to ensure that natural attenuation and degradation processes are effectively controlling discharges from the sites.

- Surface water loadings from U.S. landfills should be estimated,

in order to determine the total loading to the Niagara River.

- The absence of organic contaminants should be confirmed, particularly for the Cyanamid landfills in Niagara Falls, and the Atlas Steel landfill in Welland.

PART 8

REFERENCES

Atlas Steel, 1986. *Atlas Specialty Steels Division Atlas Landfill Site Provisional Certificate No. A120409 Operators Management Plan*

Feenstra, S., 1987. *Screening/Indicator Parameters For Organic Contaminants in Groundwater.* Water Pollution Resources Journal of Canada, Volume 22, Number 1, 1987.

Gartner Lee Ltd., 1985. *Cyanamid Canada Inc. Hydrogeological Study, Plant, Phase 1.* Prepared for Cyanamid Canada Inc.

Gartner Lee Ltd., 1986. *Cyanamid Canada Inc. Hydrogeological Study, Plant, Phase 2.* Prepared for Cyanamid Canada Inc. 2 vol.

Gartner Lee Ltd., 1987. *Cyanamid Canada Inc., Niagara Plant, Hydrogeological Investigation, Phase II(a).* Prepared for Cyanamid Canada Inc.

Gartner Lee Ltd., 1988. *Cyanamid Canada Inc., Niagara Plant, Hydrogeological Investigation Phase II(b).* Prepared for Cyanamid Canada Inc., 2 vol.

Hydrology Consultants Ltd., 1985. *Hydrogeologic Investigation at CN Rail's Victoria Avenue Landfill Site, Niagara Falls, Ontario.* Prepared for CN Rail Inc.

Morrison Beatty Ltd., 1987. *Hydrogeological Impact Studies, Bridge Street landfill Studies, Bridge Street Landfill Site.* Prepared for the Town of Fort Erie.

Morrison Beatty Ltd., 1988a. *Hydrogeological Impact Studies, Bridge Street landfill Studies, Bridge Street Landfill Site.* Prepared for the Town of Fort Erie.

Morrison Beatty Ltd., 1988b. *Addendum Report, Hydrogeological Impact Studies, Bridge Street landfill Studies, Bridge Street Landfill Site.* Prepared for the Town of Fort Erie.

Myers, J., R. Bryan, 1989. *Geostatistical Analysis of Hazardous Waste. A Short Course For the Environmental Professional.* Presented by Geostatistical Specialists, ESTOX Inc., Golden, Colorado.

NRTC (Niagara River Toxics Committee), 1984. *Report of the Niagara River Toxics Committee, October 1984.*

NRTMP (Niagara River Toxics Management Plan) River Monitoring Committee, 1987. *River Monitoring Data for the Period April 1986 to March, 1986.* Joint Report of the Niagara River Data Interpretation Group.

Odom, P., 1985. *Draft Report on Landfills on the Canadian Side of the Niagara River.* A report by the Ministry of the Environment

Niagara River Improvement Team.

Shifrin, N. Personal Communication, October 4, 1989.

Spiegel, M.R., 1968. *Mathematical Handbook of Formulas and Tables*. McGraw-Hill Book Company, Toronto, Ontario.

Terraqua Investigations Ltd., 1985. *Preliminary Hydrogeological Investigation of the Atlas Steels Landfill, Welland, Ontario*. Prepared for the Ministry of the Environment.

Terraqua Investigations Ltd., 1986. *A Hydrogeological Investigation of the Fort Erie Landfill Site*. Prepared for the Ministry of the Environment.

APPENDIX A

SITE DESCRIPTIONS OF THE SITES DELETED FROM THE LOADINGS CALCULATION

Canadian Carborundum Co. Landfills (Site #2)

Operation:	pre 1980-present
Waste:	brick, stone, concrete, asphalt, construction rubble, bauxite sweepings and dust collector fines, lagoon dredgings and magnesium reverts.
Chemical Data:	none
Soils:	(+/-) 30 m of interbedded clay and sand
Groundwater:	regional bedrock aquifer
Comments:	All wastes piled on surface, or on concrete pads

Binbrook Waste Disposal Site (Site #15)

Operation:	1971-1980
Waste:	675 T/a of waste (mostly residential with minor amounts of industrial and agricultural waste.
Chemical Data:	none
Soils:	15-30 m of varved clay and clay till
Groundwater:	groundwater movement restricted to upper fractured layer of the overburden and surface water.
Comments:	surface waters are used for watering livestock, domestic water supplies are drawn from the bedrock aquifer.

Fleet Landfill (Site #11)

Operation:	1930-1971
Waste:	paint thinners and residues, solvents, metal finishing waste products and wood wastes.
Chemical Data:	analyses indicate elevated phenolics and some metals, but all levels were at or below drinking water guideline levels.
Soils:	2-12 m of till
Groundwater:	groundwater flow is likely restricted to the shallow overburden and should not impact the regional bedrock aquifer
Comments:	repeated burnings at this site have reduced the organic contaminant concentrations

Glanbrook Regional Landfill (Site #14)

Operation:	1980-present
Waste:	licensed to handle 540,000 T/a (29% domestic, 13% commercial, 56% non-hazardous industrial, 2%

wood/paper/crates) Actual loadings have been approximately one-half of the allowable limits.

Chemical Data:	
Soils:	6-15 m of lacustrine silt, clay and clayey silt till
Groundwater:	regional bedrock aquifer is isolated from the waste by the relatively impermeable soils.
Comments:	bedrock aquifer contains naturally high concentrations of sulphate, making it unattractive for domestic use

Glanford-Mt. Hope Municipal Landfill (Site #16)

Operation:	1971-1980
Waste:	675 T/a of domestic (80%) and industrial (20%) waste.
Chemical Data:	available data indicate that no impact on either the Welland River or local water wells has occurred.
Soils:	17-30 m of glaciolacustrine clay and clay till with thin silt and sand interbeds.
Groundwater:	local aquifers in the sand and bedrock units bedrock also represents a regional aquifer.
Comments:	nearby swamp acts to attenuate leachate.

Niagara Metal Landfill (Site #3)

Operation:	pre 1956 to 1984
Waste:	iron oxide fines, ash, refractory brick, scrap metal, and coke.
Chemical Data:	no evidence of impact based on samples from a single groundwater well and one surface water sample.
Soils:	30 m of clay with sand interbeds.
Groundwater:	regional bedrock aquifer is isolated from the waste.
Comments:	wastes are relatively inert, and therefore not considered to be a problem.

Norton Company's Landfills (Site #1)

Operation:	unknown to present
Waste:	inert aluminum oxide and silicone carbide wastes with minor quantities of old tires, cars, old appliances, scrap metal etc.
Chemical Data:	evidence from surface water analyses indicate that no impact on the local surface water has occurred.

Soils:	20-30 m of interbedded clay, sand and silt.
Groundwater:	regional bedrock aquifer is isolated from the waste.
Comments:	wastes are in a stable,solid form and are not likely to be leached out. Any contaminant discharges will be limited to the shallow subsurface soil deposits, which in turn discharge to local surface waters.

Stelco Page-Hersey Works Landfill (Site #12)

Operation:	unknown-present
Waste:	inert materials
Chemical Data:	none
Soils:	not known
Groundwater:	collected by stormwater sewer system
Comments:	one storm sewer may drain into the Old Canal during severe rainfall events

Stelco Tube Works Landfill (Site #6)

Operation:	1973-1979
Waste:	excavated fill, concrete rubble, waste construction material, inert, dry industrial wastes, scrap steel and some alumina-silica welding flux material (now recycled)
Chemical Data:	no impact determined based upon surface water sampling
Soils:	40 m of clay and clay till
Groundwater:	regional bedrock aquifer is well isolated from the waste
Comments:	disposed material is deposited on surface

Welland Iron and Brass (Site #7)

Operation:	1973-1976, 1979-present
Waste:	foundry sand, cupola slag, dust, ash, and clinker waste.
Chemical Data:	no impact on local surface waters has been detected.
Soils:	40 m of clay and clay till.
Groundwater:	regional bedrock aquifer is well isolated from the waste
Comments:	methane generation in excess of the lower explosive limit has been noted on the site.

Welland Municipal Landfill (Site #13)

Operation:	1942-present
Waste:	33,200 T/a (60% domestic, 15% commercial, 1% non-hazardous solid industrial waste, 5% inert liquid sludge, 7% municipal sewage sludge, 12% rubbish and brush.
Chemical Data:	not available
Soils:	12-16 m of clay and silt.
Groundwater:	the regional bedrock aquifer is well isolated from the waste materials.
Comments:	sampling data not available, but contaminant impacts are not expected, due to the thickness, and low permeability of the overburden.

Dunlop Street Landfill

Operation:	unknown-1972
Waste:	municipal wastes from the town of Ft. Erie
Chemical Data:	not available
Soils:	not available
Groundwater:	not available
Comments:	no data available for this site

APPENDIX B

DETAILED CALCULATIONS FOR THE ATLAS STEEL LANDFILL, WELLAND

APPENDIX B1 CONTAMINANT CONCENTRATIONS, ATLAS STEEL LANDFILL, WELLAND

CONCENTRATION DATA

Well #	Sum of All Contaminants (ppm)
Downgradient Wells	
AS1-1 (High)	16.27
AS1-2 (Low)	7.14
AS1-3	9.23
AS1 (Average)	10.88
AS2-1 (High)	15.32
AS2-2	9.92
AS2-3 (Low)	3.38
AS2 (Average)	9.54
AS3-1 (Low)	15.39
AS3-2	31.14
AS3-4 (High)	46.36
AS3 (Average)	30.97
AS4-1 (Low)	14.65
AS4-2	7.60
AS4-3 (High)	10.47
AS4-4	42.28
AS4 (Average)	18.75
Averages	
High	22.10
Low	10.14
Average	17.53
Upgradient Wells	
AS-5	4.49
AS-6	10.25
AS-7	7.17
AS-8	1.62

NOTE:

The following 18 contaminants were included: Al, Ba, Be, Cd, Co, Cr, Cu, Hg, Mg, Mn, Mo, Ni Pb, Sr, Ti, V, Zn, CN.

B1 continued

CONCENTRATION CALCULATIONS

The chemical parameters listed previously were used to calulate the contaminant concentrations. The method of calculation follows that of Gradient Corp. and Geotrans Inc.

High Concentration Estimate

For the high estimate, the average of the highest contaminant concentrations in each of the downgradient nests was used, with no background correction.

therefore, C = 22.1 ppm (22,100 ppb)

Best Concentration Estimate

For the best estimate, the average of the highest contaminant concentrations in each of the downgradient nests was used, with a background correction based upon the total concentration observed in well #AS-8 (not including nitrates, which appear to be anomalously high in this monitor).

therefore, C = 22.1-1.6 ppm
= 20.5 ppm (20,500 ppb)

Low Concentration Estimate

For the low estimate, the average of the average contaminant concentrations in each of the downgradient nests was used, with a background correction based upon the total concentration observed well # AS-8 (not including nitrates, which appear to be anomalously high in this monitor).

therefore, C = 17.5-1.6 ppm
= 15.9 ppm (15,900 ppb)

APPENDIX B2 GROUNDWATER FLUX, ATLAS STEEL LANDFILL, WELLAND

DARCY'S LAW APPROACH

Data (from Terraqua Investigations, 1985)

Well	Unit	Hydraulic Conductivity (cm/s)	Hydraulic Conductivity (m/d)
AS1-1	sand	7.1E-07	6.1E-04
AS1-2	silty clay	6.5E-07	5.6E-04
AS1-3	silty clay	9.0E-08	7.8E-05
AS1-4	silty clay	5.0E-08	4.3E-05
AS1-5	berm	5.0E-08	4.3E-05
AS2-1	till	5.0E-08	4.3E-05
AS2-2	silty gravel	9.0E-08	7.8E-05
AS2-3	silty clay	7.0E-08	6.0E-05
AS3-1	silty gravel	2.5E-06	2.2E-03
AS3-2	silty clay	4.2E-07	3.6E-04
AS3-4	berm	4.0E-08	3.5E-05
AS4-1	silty clay	1.5E-07	1.3E-04
AS4-2	silty gravel	2.4E-05	2.1E-02
AS4-3	silty clay	2.0E-08	1.7E-05
AS4-4	silty clay	2.0E-06	1.7E-03
AS-5	silty clay	6.3E-07	5.4E-04
AS-6	silty clay	1.7E-06	1.5E-03
AS-8	silty clay	2.6E-06	2.2E-03
Geometric Mean		3.3E-07	2.8E-04
Arithmetic Mean		2.0E-06	1.7E-03

Darcy's Law Calculations (Q = K*i*A)

The high and best estimates of hydraulic conductivity were chosen as the arithmetic and geometric means respectively, while the gradient was estimated from the water levels in monitors AS-6 and AS-4 The saturated thickness was calculated as the measured thickness of the overburden below the water table. The unit length was taken as the length of the southern property boundary.

B2 continued

Estimate	Hydraulic Conductivity "K" (m/d)	Hydraulic Gradient "i" (m/m)	Saturated Thickness "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (L/d)
High	1.7E-03	0.07	20	320	762
Best	2.8E-04	0.07	20	320	125
Low	N/A				

Notes:

- N/A: Not Applicable
- A = (b) * (l)

WATER BUDGET APPROACH

Input Parameters

Estimated Precipitation: 94 cm/a
Potential Evapotranspiration: 61-68.5 cm/a
Runoff: large
Groundwater Inflow: little (except into bedrock)
Area Of Recharge: 51,260 m^2

Recharge:

high 15 cm/a (50 % runoff)
best 7.6 cm/a (75 % runoff)
low 0.76 cm/a (>99% runoff)

Estimate	Groundwater Flux (m^3/d)	Groundwater Flux (L/d)
High:	21	21,051
Best:	11	10,666
Low:	1	1,067

B2 continued

GROUNDWATER FLUX CALCULATIONS

High Flux Estimate

For the high estimate, the flux was determined using the water budget approach with an infiltration rate of 7.6 cm/yr.

therefore, Q = 10,666 L/d

Best Flux Estimate

For the best estimate, the flux was determined using the water budget approach with an infiltration rate of 0.76 cm/yr.

therefore, Q = 1,067 L/d

Low Flux Estimate

For the low estimate, the flux was determined using the Darcy's Law approach based upon the geometric mean of the in-situ hydraulic conductivities.

therefore, Q = 762 L/d

APPENDIX B3 GROUNDWATER LOADING, ATLAS STEEL LANDFILL, WELLAND

The groundwater loading was calculated using the the concentrations calculated in Appendix B1, and the values for flux given in Appendix B2.

High Loadings Estimate

The high estimate of contaminant loading for the Atlas Steel landfill was derived using the high estimate of the contaminant concentration and the high estimate of the groundwater flux.

Therefore, L = C(High) * Q (High)
= 22,100 * 1x10-9 * 21,051
= 0.5 kg/d

Best Loadings Estimate

The best estimate of contaminant loading for the Atlas Steel landfill was derived using the best estimate of the contaminant concentration and the best estimate of the groundwater flux.

Therefore, L = C(Best) * Q (Best)
= 20,500 * 1x10-9 * 10,666
= 0.2 kg/d

Low Loadings Estimate

The low estimate of contaminant loading for the Atlas Steel landfill was derived using the low estimate of the contaminant concentration and the low estimate of the groundwater flux.

Therefore, L = C(Low) * Q (Low)
= 15,900 * 1x10-9 * 762
= 0.01 kg/d

APPENDIX B4 SURFACE WATER LOADING, ATLAS STEEL LANDFILL, WELLAND

SURFACE WATER CONCENTRATIONS

General Chemistry (7 sampling dates, 1982-1988)

PARAMETER	Detection Limits (ppm)	1986-1988* Average (ppm)	1982-1988 Average (ppm)
Chloride,Unfilt.React.(as Cl-)	0.1	440.33	1013.86
Phosphorus,Unfilt.Total(as P)	0.004	0.01	0.07
Phosphates, Reactive (as P)	0.003	0.02	0.01
TKN,Unfilt.React.(as N)	0.06		
NO3+NO2 (as N)	0.005	23.13	29.14
NO2 (as N)	0.003	8.03	5.64
NO3 (as N)	0.05	15.11	23.53
Solvent Extractables	1	2.33	2.14
Phenolics,Unf.React. (4AAP)	0.0002	0.0078	0.03
Concentration, all compounds		465.84	1074.42
Concentration, phenol only		0.01	0.03

* more representative because remediation in 1984 to 1986 solved the acid pit problem.

B4 continued

Metals (7 sampling dates, 1982-1988)

PARAMETER	Detection Limits (ppm)	1986-1988* Average (ppm)	1982-1988 Average (ppm)
Silver, Unfilt.Total (as Ag)	0.005	0.000	0.000
Aluminum, Unfilt.Total (as Al)	0.01	0.400	0.498
Arsenic, Unfilt.Total (as As)	0.001	0.002	0.001
Barium, Unfilt.Total (as Ba)	0.001	0.210	0.156
Beryllium, Unfilt.Total (as Be)	0.001	0.000	0.000
Cadmium, Unfilt.Total (as Cd)	0.001	0.000	0.006
Cobalt, Unfilt.Total (as Co)	0.001	0.000	0.088
Cyanide, Avail.Unf.React. (as CN)	0.001	0.084	0.053
Chromium, Unfilt.Total (as Cr)	0.001	0.250	0.129
Copper, Unfilt.Total (as Cu)	0.003	0.013	0.008
Mercury, Unfilt.Total (as Hg)	0.00001	0.000	0.000
Manganese, Unfilt.Total (as Mn)	0.001	0.020	2.950
Molybdenum, Unfilt.Total (as Mo)	0.001	4.033	2.725
Nickel, Unfilt.Total (as Ni)	0.002	0.024	1.716
Lead, Unfilt.Total (as Pb)	0.002	0.000	0.025
Antimony, Unfilt.Total (as Sb)	0.001	0.000	0.000
Selenium, Unfilt.Total (as Se)	0.001	0.009	0.015
Strontium, Unfilt.Total (as Sr)	0.01	0.780	1.119
Titanium, Unfilt.Total (as Ti)	0.002	0.003	0.013
Thallium, Unfilt.Total (as Tl)	0.002	0.000	0.000
Vanadium, Unfilt.Total (as V)	0.001	0.000	0.000
Zinc, Unfilt.Total (as Zn)	0.003	0.010	0.093
Total Concentration		5.837	9.792

* more representative because remediation in 1984 to 1986 solved the acid pit problem.

B4 continued

Organics (7 sampling dates, 1982-1988)

PARAMETER	Detection Limits (ppm)	1986-1988* Average (ppm)	1982-1988 Average (ppm)
Dichloromethane (Methylene Cl.)	0.0001	0.0001	0.0013
Chloroform	0.0001	0.0002	0.0002
Dichlorobromomethane	0.0001	0.0001	0.0001
1,1,1-Trichloroethane	0.0001	0.0001	0.0001
1,1-Dichloroethylene	0.0001	0.0001	0.0001
trans 1,2-Dichloroethylene	0.0001	0.0001	0.0006
cis 1,2-Dichloroethylene	0.0001	0.0001	0.0001
Trichloroethylene	0.0001	0.0009	0.0084
Benzene	0.0001	0.0001	0.0001
Toluene	0.0001	0.0001	0.0005
ortho-Xylene	0.0001	0.0001	0.0001
meta-Xylene	0.0001	0.0001	0.0001
Diethyl Phthalate	0.001	0.0010	0.0009
Dibutyl Phthalate	0.001	0.0010	0.0009
Di-n-octyl Phthalate	0.001	0.0070	0.0034
Di-isooctyl Phthalate	0.001	0.0010	0.0010
A-BHC(A-Hexachlorocyclohexane)	0.000001	0.0000	0.0000
G-BHC(G-Hexachlorocyclohexane)	0.000001	0.0000	0.0000
p,p'-DDE (DDX)	0.000001	0.0000	0.0000
Note: A total of 180 organics were tested for.			
Total		0.012	0.018

* more representative because remediation in 1984 to 1986 solved the acid pit problem.

B4 continued

SURFACE WATER CONCENTRATION CALCULATIONS

PARAMETERS	1986-1988 Average (ppm)	1982-1988 Average (ppm)
Surface Water Flow (L/s)		
Average	1	1
Summary, Surface Water Concentrations (ppm)		
Phenols	0.01	0.03
Metals	5.84	9.79
Organics	1.2E-02	1.8E-02
Total	5.9	9.8
Summary, Surface Water Loadings (kg/d)		
Phenols	0.00	0.00
Metals	0.50	0.85
Organics	0.00	0.00
Total	0.51	0.85

Note:

- The total loading averaged from 1986 to 1988 will be used in all further calculations, since remediation in 1984-1986 has solved the acid pit problem.

Appendix B5 Total Loading, Atlas Steel Landfill, Welland

The total loadings were calculated from the groundwater loadings provided in Appendix B3, and the surface water loadings, as given in Appendix B4.

High Estimate

The high estimate of the total contaminant loading for the Atlas Steel Landfill was derived by using the high estimate of the groundwater loading, and adding the three year average of the surface water loading.

Therefore, L = 0.5 + 0.5
= 1.0 kg/d

Best Estimate

The best estimate of the total contaminant loading for the Atlas Steel Landfill was derived by using the best estimate of the groundwater loading, and adding the three year average of the surface water loading.

Therefore, L = 0.2 + 0.5
= 0.7 kg/d

Low Estimate

The low estimate of the total contaminant loading for the Atlas Steel Landfill was derived by using the low estimate of the groundwater loading, and adding the three year average of the surface water loading.

Therefore, L = 0.01 + 0.5
= 0.5 kg/d

APPENDIX C

DETAILED CALCULATIONS FOR THE CYANAMID WELLAND PLANT SITE

APPENDIX C1: CONTAMINANT CONCENTRATIONS, CYANAMID INC. LANDFILL, WELLAND

CONCENTRATION DATA (2 data sets: October, November, 1985)

Parameter/ Well #	NO2 (ppb)	NO3 (ppb)	TKN (ppb)	F (ppb)	Fe (ppb)	CN- Total (ppb)	CN- + F (ppb)
Bedrock Monitors: Concentrations to Welland River							
1-I	200	2,750	425	1,700	505	7	1,707
2-I	200	2,750	275	1,300	500	8	1,308
3-I	200	2,750	450	1,200	95	7	1,207
4-I	200	2,750	1,115	650	40	5	655
5-I	200	2,750	1,015	1,600	45	4	1,604
Average	200	2,750	656	1,290	237	6	1,296
Overburden Monitors: Concentrations to Welland River							
4-III	200	275	175	275	405	7	282
5-III	600	36,100	280	2,050	35	9	2,059
5-IV	450	67,500	570	1,550	35	11	1,561
12-I	950	283,000	1,035	525	35	4	529
12-II	500	221,500	575	1,340	35	8	1,348
13-I	185	275	1,550	1,250	145	5	1,255
13-II	500	275	780	300	10	5	305
14-I	200	204,500	1,005	8,100	60	15	8,115
14-II	200	249,000	425	6,400	60	21	6,421
15-I	200	500	1,055	6,100	520	39	6,139
Average	399	106,293	745	2,789	134	12	2,801
Creek Monitors: Overburden Concentrations to Thompson Creek							
C1	350	5,250	1,750	3,700	380	33	3,733
C2	350	5,250	10,050	3,700	425	33	3,733
C3	750	5,250	1,200	3,700	80	56	3,756
C4	9,750	6,250	14,350	3,700	20	62	3,762
C5	350	37,500	3,150	3,700	70	32	3,732
C6	350	66,000	62,050	3,700	400	23	3,723
C7	12,050	52,000	37,550	3,700	1,415	20	3,720
C8	1,250	66,000	45,750	3,700	815	35	3,735
C9	48,600	36,500	48,850	3,700	2,215	20	3,720
C10	350	5,000	950	3,700	15	15	3,715
Average	7,415	28,500	22,565	3,700	584	33	3,733

C1 continued

CONCENTRATION CALCULATIONS

The average concentrations of CN- and Fluorine listed above were used to estimate contaminant loadings. Due to difficulty in locating a suitable background well, no background corrections were made. The constituents used are those expected from the site. Analyses for metals showed no significant increases above normal groundwater concentrations.

Best Concentration Estimate

Contaminant concentrations were calculated for the overburden both to the Welland River and to Thompson Creek. The bedrock contaminant concentration was also calculated.

Since only limited data were available, high and low estimates were not calculated and the best estimate was used for all the loading calculations.

Bedrock

To: Welland River

C = 1,296 ppb

Overburden

To: Welland River

C = 2,801 ppb

To: Thompson's Creek

C = 3,733 ppb

APPENDIX C2 GROUNDWATER FLUX, CYANAMID INC. LANDFILL, WELLAND

BEDROCK FLUX TO THE WELLAND RIVER (Darcy's Law Approach, Q=k*i*A)

Based on the geometric mean of five (5) tests performed by Gartner Lee Limited, the hydraulic conductivity of the upper bedrock is 3.2 x 10-6 m/s, or 0.3 m/d, with a range from 9.9 x 10-6 m/s to 5.2 x 10-7 m/s. The extremes were used as the high and low estimates. The hydraulic gradient was calculated based upon the water levels in OW-1 and OW-4. The thickness of the weathered zone of the bedrock was used as the saturated thickness.

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	8.6E-01	0.001	4	2150	7.41	7415
Best	3.0E-01	0.001	4	2150	2.60	2601
Low	4.5E-02	0.001	4	2150	0.39	389

OVERBURDEN FLUX TO WELLAND RIVER/THOMPSON CREEK (Darcy's Law Approach, Q=K*i*A)

Based on the geometric mean of 17 tests performed by Gartner Lee Limited, the hydraulic conductivity of the upper fractured clay is 1.2 x 10-8 m/s, or 0.001 m/d, with a range from 2.5 x 10-9 m/s to 6.6 x 10-7 m/s. The extremes were used as the high and low estimates. Gradients were calculated from the water levels in wells OW-3, OW-4 and OW-6, and OW-18. The gradients appear to be relatively constant across the site. The thickness of the contributing zone was taken as the thickness of the fractured clay lying below the water table.

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	5.7E-02	0.006	4	2200	3.01	3011
Best	1.0E-03	0.006	4	2200	0.05	55
Low	2.2E-04	0.006	4	2200	0.01	11

Notes:

- A = (b) * (l)
- E = Exponent

APPENDIX C3 GROUNDWATER LOADING, CYANAMID INC., WELLAND

The contaminant loadings were estimated to both the Welland River and Thompson Creek. The determinations of the contaminant concentrations and groundwater flux are discussed in Appendix C1 and C2 respectively.

The high, best, and low estimates were determined by multiplying the concentrations by the high, best, and low estimates of the groundwater flux for both overburden and bedrock. Since the bedrock aquifer does not drain into Thompson Creek, only the overburden loading was estimated.

The total loadings were then assumed to equal the sum of the individually calculated loadings.

High Groundwater Loadings Estimate

The high estimate of the groundwater loading was derived by multiplying the high estimates of the contaminant concentrations by the high estimates of the groundwater flow for both overburden and bedrock for the Welland River, and for the overburden alone for Thompson Creek.

Receiver: Welland River

L = C(bedrock, high) * Q(bedrock, high) + C(overburden, high) * Q(overburden, high)

L = 1296 * 1x10-9 * 7,415 + 2,801 * 1x10-9 * 3011

L = 0.02 kg/d

Receiver: Thompson's Creek

L = C(overburden, high) * Q(overburden, high)

L = 3,733 * 1x10-9 * 3011

L = 0.01 kg/d

Total

L = 0.02 + 0.01

L = 0.03 kg/d

C3 continued

Best Groundwater Loadings Estimate

The best estimate of the groundwater loading was derived by multiplying the best estimates of the contaminant concentrations by the best estimates of the groundwater flow for both overburden and bedrock for the Welland River, and for the overburden alone for Thompson Creek.

Receiver: Welland River

L = C(bedrock, best) * Q(bedrock, best) +
C(overburden, best) * Q(overburden, best)

L = 1,296 * 1x10-9 * 2601 +
2,801 * 1x10-9 * 55

L = 0.004 kg/d

Receiver: Thompson Creek

L = C(overburden, best) * Q(overburden, best)

L = 3733 * 1x10-9 * 55

L = 0.0002 kg/d

Total

L = 0.004 + 0.0002

L = 0.0042 kg/d

C3 continued

Low Groundwater Loadings Estimate

The low estimate of the groundwater loading was derived by multiplying the low estimates of the contaminant concentrations by the low estimates of the groundwater flow for both overburden and bedrock for the Welland River, and for the overburden alone for Thompson Creek.

Receiver: Welland River

L = C(bedrock, low) * Q(bedrock, low) + C(overburden, low) * Q(overburden, low)

L = 1296 * 1x10-9 * 389 + 2801 * 1x10-9 * 11

L = 0.001 kg/d

Receiver: Thompson Creek

L = C(overburden, low) * Q(overburden, low)

L = 3,733 * 1x10-9 * 11

L = 0.00004 kg/d

Total

L = 0.001 + 0.00004

L = 0.001 kg/d

APPENDIX D

DETAILED CALCULATIONS FOR THE CYANAMID SATELLITE SITES, NIAGARA FALLS

APPENDIX D] CYANAMID INC. LANDFILLS, NIAGARA FALLS

CONCENTRATION DATA (1987, 1988, 2 runs, averaged)

Concentration to Queenston-Chippawa Power Canal

Parameter/ Well #	CN- (Total) (ppm)	TKN (ppm)	NO2 (ppm)	NO3 (ppm)	Sum of All Contaminants (ppm)
Bedrock					
A1-7-I	0.07	239.00	0.02	0.06	239.15
A1-8-I	0.45	152.00	0.01	0.05	152.51
A1-9-I	0.65	77.60	0.01	0.05	78.31
B1-7-I	58.00	211.50	0.01	0.05	269.56
B1-8-I	8.22	93.80	0.01	0.05	102.08
C1-4-I	1.94	43.65	0.22	0.05	45.86
C1-5-I	25.55	143.50	0.03	0.05	169.13
Average	13.55	137.29	0.04	0.05	150.94
Overburden					
A1-7-II,III	0.03	72.45	0.02	0.08	72.58
A1-8-II	0.06	1.88	0.01	0.05	2.00
A1-9-II	0.14	2.73	0.03	0.05	2.95
B1-7-II,III	186.30	357.50	1.00	0.25	545.05
B1-8-II,III	0.90	227.50	0.31	7.00	235.71
C1-4-II	18.15	177.00	2.47	0.8	198.42
C1-5-II	0.07	1.55	0.01	0.03	1.66
Average	29.38	120.09	0.55	1.18	151.20

D1 continued

Concentration to Niagara River via St. David's Buried Gorge

Parameter/ Well #	CN- (Total) (ppm)	TKN (ppm)	NO2 (ppm)	NO3 (ppm)	Sum of All Contaminants (ppm)
Bedrock					
B1-11-I	0.07	1.62	0.01	0.05	1.75
C1-5-I	25.55	143.50	0.03	0.05	169.13
C1-6-I	73.50	160.50	0.11	0.05	234.16
C1-7-I	0.33	1.64	0.01	0.05	2.03
Average	24.86	76.82	0.04	0.05	101.77
Overburden					
B1-11-II	0.02	0.68	0.01	0.05	0.76
C1-5-II	0.07	1.55	0.03	0.05	1.70
C1-6-II,III	0.11	1.13	0.01	2.25	3.49
C1-7-II,III	0.01	1.02	0.01	0.05	1.08
Average	0.05	1.09	0.02	0.60	1.76

Concentration to Niagara River

Parameter/ Well #	CN- (Total) (ppm)	TKN (ppm)	NO2 (ppm)	NO3 (ppm)	Sum of All Contaminants (ppm)
Bedrock					
B1-1-I	1.14	4.54	0.01	0.05	5.74
B1-9-I	4.84	69.80	0.01	0.05	74.70
B1-10-I	1.10	21.20	0.01	0.05	22.36
B1-11-I	0.07	1.62	0.01	0.05	1.75
Average	1.78	24.29	0.01	0.05	26.13
Overburden					
A2-6-I	0.36	6.40	0.06	0.05	6.76
B1-10-II	0.38	41.00	0.01	0.05	41.38
TW-4-I	301.50	2,474	0.28	0.05	2,776
B1-11-II	0.02	0.68	0.01	0.05	0.70
Average	75.56	630.52	0.09	0.05	706.08

D1 continued

CONCENTRATION CALCULATIONS (Cyanide only)

Only best estimates of the chemical concentrations were made due to the lack of a clearly distinguishable background well. The nitrogen based compounds were not included, since they are not priority pollutants.

Receiver	Concentration (ppm)	
	Bedrock	Overburden
Queenston-Chippawa Power Canal	13.6	29.4
Niagara R. via Buried Gorge	24.9	0.05
Niagara River	1.8	75.6

APPENDIX D2 GROUNDWATER FLUX, CYANAMID INC. LANDFILLS, NIAGARA FALLS

BEDROCK FLUX (Darcy's Law Approach, Q = K*i*A)

Based on the geometric mean of 13 tests performed by Gartner Lee Limited, the hydraulic conductivity of the upper bedrock is 1.6 x 10-5 m/s, or 1.4 m/day with a range from 2 x 10-4 m/s to 8 x 10-5 m/s. The mean value was used as the best estimate, while the extremes were used as the high and low estimates. The hydraulic gradients were determined by measuring the distance between contour lines on the bedrock flow map prepared by Gartner Lee Limited (1988). The high and low values represent the possible extremes, while the best estimate was taken as the average gradient to the receiver. The saturated thickness of 4 m was determined by Gartner Lee Limited (1988) to be the extent of the weathered zone of the bedrock.

Flux to Queenston-Chippawa Power Canal

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	7.8E+00	0.05	4	1200	1,866	1,866,240
Best	1.4E+00	0.04	4	1200	269	268,800
Low	1.7E-01	0.03	4	1200	25	24,883

Flux to Niagara River via St. David's Buried Gorge

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	7.8E+00	0.05	4	300	467	466,560
Best	1.4E+00	0.04	4	300	67	67,200
Low	1.7E-01	0.03	4	300	6	6,221

D2 continued

Flux to the Niagara River

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	7.8E+00	0.05	4	300	467	466,560
Best	1.4E+00	0.04	4	300	67	67,200
Low	1.7E-01	0.03	4	300	6	6,221

Notes:

- A - (b) * (l), E - Exponential

OVERBURDEN FLUX (Darcy's Law Approach, Q - K*i*A)

The hydraulic conductivity values were determined for silty clay soils (5 tests) and silt and silty sand soils (23 tests). The best estimate of the values was chosen as the arithmetic average of the two, while the value for clay was used as the low estimate, and the value for silt and silty sand soils was used for the high estimate. Hydraulic gradients were calculated from the water table potentiometric surface map completed by Gartner Lee Limited (1988). The high and low values represent the extreme cases, while the best estimate is an average of the gradients to the receiver. The thickness values are representative of the highest, lowest, and average thicknesses of the overburden in each of the areas of concern based upon the drill logs for the site.

Flux to Queenston-Chippawa Power Canal

Estimate	Hydraulic Cond. "k" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	7.1E-01	0.30	11	1200	2,806	2,805,581
Best	3.6E-01	0.16	8	1200	557	557,384
Low	1.2E-02	0.04	6	1200	3	3,484

D2 Continued

Flux to St. David's Buried Gorge

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	7.1E-01	0.06	10	300	128	127,526
Best	3.6E-01	0.06	8	300	52	52,255
Low	1.2E-02	0.06	8	300	2	1,742

Flux to Niagara River

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	7.1E-01	0.06	10	300	128	127,526
Best	3.6E-01	0.06	8	300	52	52,255
Low	1.2E-02	0.06	6	300	1	1,306

Notes:

- A = (b) * (l), E = Exponential

APPENDIX D3 GROUNDWATER LOADINGS, CYANAMID INC. LANDFILLS, NIAGARA FALLS

The groundwater loading calculations are based upon the chemical concentration data provided in Appendix D1, and the groundwater flux calculations detailed in Appendix D2.

High Groundwater Loadings Estimate

The high estimate of the groundwater loading was derived by multiplying the high estimates of the contaminant concentrations by the high estimates of the groundwater flow for both overburden and bedrock, for each of the three receivers.

Receiver: Queenston-Chippawa Power Canal

L = C(bedrock, high) * Q(bedrock, high) + C(overburden, high) * Q(overburden, high)

L = 13,600 * 1x10-9 * 1,866,240 + 29,400 * 1x10-9 * 2,805,581

L = 107.9 kg/d

Receiver: Niagara River via St. David's Buried Gorge

L = C(bedrock, high) * Q(bedrock, high) + C(overburden, high) * Q(overburden, high)

L = 24,900 * 1x10-9 * 466,560 + 50 * 1x10-9 * 127,526

L = 11.6 kg/d

Receiver: Niagara River

L = C(bedrock, high) * Q(bedrock, high) + C(overburden, high) * Q(overburden, high)

L = 1,800 * 1x10-9 * 466,560 + 75,600 * 1x10-9 * 127,526

L = 10.5 kg/d

Total

L = L(Queenston-Chippawa Power Canal) + L(St. David's Buried Gorge)+ L(Niagara River)

L = 107.9 + 11.6 + 10.5

L = 130.0 kg/d

D3 continued

Best Groundwater Loadings Estimate

The best estimate of the groundwater loading was derived by multiplying the best estimates of the contaminant concentrations by the best estimates of the groundwater flow for both overburden and bedrock, for each of the three receivers.

Receiver: Queenston-Chippawa Power Canal

L = C(bedrock, best) * Q(bedrock, best) + C(overburden, best) * Q(overburden, best)

L = 13,600 * 1x10-9 * 268,800 + 29,400 * 1x10-9 * 557,384

L = 20.0 kg/d

Receiver: Niagara River via St. David's Buried Gorge

L = C(bedrock, best) * Q(bedrock, best) + C(overburden, best) * Q(overburden, best)

L = 24,900 * 1x10-9 * 67,200 + 50 * 1x10-9 * 52,255

L = 1.7 kg/d

Receiver: Niagara River

L = C(bedrock, best) * Q(bedrock, best) + C(overburden, best) * Q(overburden, best)

L = 1,800 * 1x10-9 * 67,200 + 75,600 * 1x10-9 * 52,255

L = 4.1 kg/d

Total

L = L(Queenston-Chippawa Power Canal) + L(St. David's Buried Gorge)+ L(Niagara River)

L = 20.0 + 1.7 + 4.1

L = 25.8 kg/d

D3 continued

Low Groundwater Loadings Estimate

The low estimate of the groundwater loading was derived by multiplying the low estimates of the contaminant concentrations by the low estimates of the groundwater flow for both overburden and bedrock, for each of the three receivers.

Receiver: Queenston-Chippawa Power Canal

L = C(bedrock, low) * Q(bedrock, low) + C(overburden, low) * Q(overburden, low)

L = 13,600 * 1x10-9 * 24,883 + 29,400 * 1x10-9 * 3,484

L = 0.4 kg/d

Receiver: Niagara River via St. David's Buried Gorge

L = C(bedrock, low) * Q(bedrock, low) + C(overburden, low) * Q(overburden, low)

L = 24,900 * 1x10-9 * 6,221 + 50 * 1x10-9 * 1,742

L = 0.2 kg/d

Receiver: Niagara River

L = C(bedrock, low) * Q(bedrock, low) + C(overburden, low) * Q(overburden, low)

L = 1,800 * 1x10-9 * 6,221 + 75,600 * 1x10-9 * 1,306

L = 0.1 kg/d

Total

L = L(Queenston-Chippawa Power Canal) + L(St. David's Buried Gorge)+ L(Niagara River)

L = 0.4 + 0.2 + 0.1

L = 0.7 kg/d

APPENDIX D4 SURFACE WATER LOADING, CYANAMID INC., LANDFILLS, NIAGARA FALLS

Surface Water Loading to the Queenston-Chippawa Power Canal
(12 analyses per site, 1982-1988)

Parameter	SW-1	SW-2	SW-17	Total
Flow (L/s)	0.2	0.5	161.8	162.6
Total Cyanide (mg/L)	23.9	4.5	0.0	28.4
TKN (mg/L)	72.4	47.7	N/A	120.1
NO2 (mg/L)	50.2	32.8	N/A	82.9
NO3 (mg/L)	23.2	9.4	N/A	32.6
Cyanide Concentration (mg/L)	23.9	4.5	0.0	28.4
Cyanide Loading (kg/d)	0.4	0.2	0.1	0.7

Surface Water Loading to the Niagara River
(SW-14: 8 analyses, SW-15: 6 analyses, 1982-1988)

Parameter	SW-14	SW-15	Total
Flow (L/s)	181.1	0.4	181.5
Total Cyanide (mg/L)	0.0	0.5	0.5
TKN (mg/L)	N/A	N/A	N/A
NO2 (mg/L)	N/A	N/A	N/A
NO3 (mg/L)	N/A	N/A	N/A
Cyanide Concentration (mg/L)	0.0	0.5	0.5
Cyanide Loading (kg/d)	0.4	0.0	0.4

N/A: Not Analysed

APPENDIX D5 TOTAL LOADINGS, CYANAMID INC. LANDFILLS, NIAGARA FALLS

The loading calculations for this site assume that natural attenuation and/or biodegradation of cyanide do not occur. This was done to ensure that the data are comparable to the results published by Gradient Corp. and Geotrans Inc. for the US sites. Ignoring these factors will result in an overestimate of the loadings. Gartner Lee Limited, (1988) has suggested that the overburden does not contribute contaminants to the Niagara River. If this is true, the total loading will be approximately 20 kg/d less than the values stated below.

High Total Loadings Estimate

The high estimate of the total loading was derived by adding the high estimates of the groundwater loading and the surface water loading for each of the three receivers.

Receiver: Queenston-Chippawa Power Canal

L = L (groundwater) + L (surface water)
L = 107.9 + 0.7
L = 108.6 kg/d

Receiver: Niagara River via St. David's Buried Gorge

L = L (groundwater)
L = 11.6 kg/d

Receiver: Niagara River

L = L (groundwater) + L (surface water)
L = 10.5 + 0.4
L = 10.9 kg/d

Total

L = L(Queenston-Chippawa Power Canal) + L(St. David's Buried Gorge)+ L(Niagara River)

L = 108.6 + 11.6 + 1 9
L = 259.0 kg/d

D5 continued

Best Total Loadings Estimate

The best estimate of the total loading was derived by adding the best estimates of the groundwater loading and the surface water loading for each of the three receivers.

Receiver: Queenston-Chippawa Power Canal

L = L (groundwater) + L (surface water)
L = 20.0 + .7
L = 20.7 kg/d

Receiever: Niagara River via St. David's Buried Gorge

L = L (groundwater)
L = 1.7 kg/d

Receiver: Niagara River

L = L (groundwater) + L (surface water)
L = 4.1 + 0.4
L = 4.5 kg/d

Total

L = L(Queenston-Chippawa Power Canal) + L(St. David's Buried Gorge)+ L(Niagara River)

L = 20.7 + 1.7 + 4.5
L = 26.9 kg/d

D5 continued

Low Total Loadings Estimate

The low estimate of the total loading was derived by adding the low estimates of the groundwater loading and the surface water loading for each of the three receivers.

Receiver: Queenston-Chippawa Power Canal

L = L (groundwater) + L (surface water)
L = 0.4 + 0.7
L = 1.1 kg/d

Receiever: Niagara River via St. David's Buried Gorge

L = L (groundwater)
L = 0.2 kg/d

Receiver: Niagara River

L = L (groundwater) + L (surface water)
L = 0.1 + 0.4
L = 0.5 kg/d

Total

L = L(Queenston-Chippawa Power Canal) + L(St. David's Buried Gorge)+ L(Niagara River)

L = 1.1 + 0.2 + 0.5
L = 1.8 kg/d

APPENDIX E

DETAILED CALCULATIONS FOR THE BRIDGE STREET LANDFILL, FORT ERIE

APPENDIX E1 CONTAMINANT CONCENTRATIONS, BRIDGE STREET LANDFILL, FORT ERIE

CONCENTRATION DATA, OVERBURDEN WELLS

(Feb, May 1988 data, 2 data sets, averaged)

Monitor Well/ Parameter	BH-5 1 well	OW-2 2 wells	OW-3 1 well	OW-23 2 wells	OW-29 2 wells	OW-30 1 well	Average
Inorganics (ppm)							
Nitrate	0.300	0.525	0.100	0.650	0.175	0.100	0.308
Nitrite	0.100	0.100	0.100	0.100	0.100	0.100	0.100
TKN	0.100	0.100	0.215	0.100	0.100	0.100	0.119
Phenol	0.001	0.001	0.003	0.001	0.001	0.004	0.002
Iron	0.100	0.225	0.150	1.000	0.138	0.375	0.331
Manganese	0.020	0.200	0.060	0.030	0.055	0.050	0.069
Organics (ppb)							
34 compounds, 1 run							
Dichloromethane	5.860	0.001		0.001			1.954
Chloroform	1.000	0.001		0.001			0.334
1,1,1-trichloroethane	1.390	0.001		0.001			0.464
toluene	0.000	0.001		0.001			0.001
tetrachloroethylene	1.000	0.001		0.001			0.334
P&M Xylene	0.001	0.001		0.001			0.001
O-Xylene	0.001	0.001		0.001			0.001
Total (phenol)	0.001	0.001	0.003	0.001	0.001	0.004	0.002
Total (organics)	9.252	0.007		0.007			3.089
Total (ppb)	10	1	3	1	1	4	3

E1 continued

CONCENTRATION DATA, BEDROCK WELLS
(Feb, May 1988 data, 2 data sets, averaged)

Monitor Well/ Parameter	OW-19 2 wells	OW-24 2 wells	OW-25 2 wells	OW-29 2 wells	OW-30 2 wells	Average
Inorganics (ppm)						
Nitrate	0.375	1.175	2.550	0.100	0.100	0.860
Nitrite	0.100	0.100	1.275	0.100	0.100	0.335
TKN	0.100	0.325	0.100	0.200	2.100	0.565
Phenol	0.001	0.001	0.001	0.001	0.006	0.002
Iron	0.150	0.075	0.188	0.125	0.250	0.158
Manganese	0.020	0.060	0.025	0.025	0.045	0.035
Organics (ppb)						
34 compounds, 1 run						
Dichloromethane				0.001	0.001	0.001
Chloroform				1.000	1.000	1.000
1,1,1trichloroethane				0.001	0.001	0.001
toluene				0.001	0.800	0.401
tetrachloroethylene				0.001	0.001	0.001
P&M Xylene				0.001	0.500	0.251
O-Xylene				0.001	0.500	0.251
Total (phenol-ppm)	0.001	0.001	0.001	0.001	0.006	0.002
Total (organics-ppb)				1.006	2.803	1.905
Total (Phenol+Org.-ppb)	1	1	1	2	9	3

APPENDIX E2 GROUNDWATERFLUX, BRIDGE STREET LANDFILL, FORT ERIE

BEDROCK FLUX (Darcy's Law Approach, Q=K*i*A)

Based on two (2) pump tests performed by Morrison Beatty Limited, the hydraulic conductivity of the upper bedrock is 6 x 10-4 m/s, or 51.8 m/d. The best estimate of the gradient was determined from OW-17 to OW-25. The high estimate was determined using OW-17 and OW-3. The low estimate was used by Morrison-Beatty. The thickness was taken as the weathered zone of the bedrock.

Estimate	Hyd. Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	5.2E+01	0.020	4	1500	6.22E+03	6,220,800
Best	5.2E+01	0.015	4	1500	4.67E+03	4,665,600
Low	5.2E+01	0.004	4	1500	1.24E+03	1,244,160

WEATHERED CLAY OVERBURDEN FLUX (Darcy's Law Approach, Q=k*i*A)

Based on the arithmetic average of five (5) tests performed by Morrison Beatty Limited, the best estimate of the hydraulic conductivity of the clay is 4 x 10-8 m/s (3.5 x 10-3 m/d). The low and high values were used as the low and high estimates respectively. The gradient was taken as the average gradient between OW-17 and OW-27 The thickness was taken as the average thickness of the weathered zone below the water table.

Estimate	Hyd. Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	8.6E-03	0.011	5	1500	7.13E-01	713
Best	3.5E-03	0.011	5	1500	2.85E-01	285
Low	3.5E-04	0.011	5	1500	2.85E-02	29

Notes:

- A = (b) * (l)
- E = Exponent

E2 continued

GLACIAL/INTERGLACIAL OVERBURDEN FLUX (Darcy's Law Approach, Q=k*i*A)

Based on the arithmetic average of nine (9) tests performed by Morrison Beatty Limited, the best estimate of the hydraulic conductivity of the clay is 8 x 10-7 m/s (6.9 x 10-2 m/d). The low and high values were used as the low and high estimates respectively. The gradient was taken as the average gradient between OW-17 and OW-27. The thickness was taken as the average width of this unit.

Estimate	Hyd. Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	2.6E-01	0.011	5	1500	2.14E+01	21,384
Best	6.9E-02	0.011	5	1500	5.70E+00	5,702
Low	1.7E-04	0.011	5	1500	1.43E-02	14

Notes:

- A = (b) * (l)
- E = Exponent

APPENDIX E3 GROUNDWATER LOADINGS, BRIDGE STREET LANDFILL, FORT ERIE

The loadings calculations are based upon the groundwater concentration data presented in Appendix E1, and the groundwater flux determinations shown in Appendix E2.

High Groundwater Loadings Estimate

The high estimate of contaminant loading for the Bridge Street Landfill was derived by multiplying the estimates of both overburden and bedrock contaminant concentrations by the high estimates of the groundwater fluxes for each of the three stratigraphic units.

Therefore, L = C (Overburden) * Q (Weathered Clay, high) +
C (Overburden) * Q (Glacial/Interglacial, high) +
C (Bedrock) * Q (Bedrock, high)
= 3 * 1x10-9 * 713 + 3 * 1x10-9 * 21,384 +
3 * 1x10-9 * 6,220,800
= 0.02 kg/d

Best Groundwater Loadings Estimate

The best estimate of contaminant loading for the Bridge Street Landfill was derived by multiplying the estimates of both overburden and bedrock contaminant concentrations by the best estimates of the groundwater fluxes for each of the three stratigraphic units.

Therefore, L = C (overburden) * Q (Weathered Clay, best) +
C (Overburden) * Q (Glacial/Interglacial, best) +
C (Bedrock) * Q (Bedrock, best)
= 3 * 1x10-9 * 285 + 3 * 1x10-9 * 5,702 +
3 * 1x10-9 * 4,665,600
= 0.01 kg/d

Low Groundwater Loadings Estimate

The low estimate of contaminant loading for the Bridge Street Landfill was derived by multiplying the estimates of both overburden and bedrock contaminant concentrations by the low estimates of the groundwater fluxes for each of the three stratigraphic units.

Therefore, L = C (overburden) * Q (Weathered Clay, low) +
C (Overburden) * Q (Glacial/Interglacial, low) +
C (Bedrock) * Q (Bedrock, low)
= 3 * 1x10-9 * 29 + 3 * 1x10-9 * 14
3 * 1x10-9 * 1,244,160
= 0.004 kg/d

Appendix E4 Surface Water Loadings, Bridge Street Landfill, Fort Erie (NIAMIS Data)

GENERAL CHEMISTRY DATA (*)

Station FELF1: 1982-1986; 4 analyses, Stations S3,S4: 1986; 4 analyses)

Sample Location		FELF1	S3	S4	S3+S4
PARAMETER	Detection Limits	Average	Average	Average	Average
Flow (l/s)	N/A	2.233	0.342	1.567	N/A
Chloride,Unfilt.React.(as Cl-)	0.1	132.175	35.425	114.425	149.85
Sulphate			39.013	225.938	264.95
Phosphorus,Unfilt.Total(as P)	0.004	0.540	0.087	0.187	0.27333
Phosphates, Reactive (as P)	0.003	0.293	0.048	0.036	0.084
TKN,Unfilt.React.(as N)	0.06	6.575	1.525	2.420	3.945
NO3+NO2 (as N)	0.005	4.050	0.881	1.817	2.698
Solvent Extractables	1	1.500			0
Phenolics,Unf.React. (4AAP)	0.0002	0.004	0.652	3.052	3.7035
Total Concentration (mg/L)		145.14	77.63	347.87	425.50
Phenol Concentration (mg/L)		0.004	0.65	3.05	3.70
Total Loading (kg/d)		28.0	2.3	47.1	49.4
Phenol Loading (kg/d)		0.001	0.02	0.41	0.4

* Data obtained from MOE files.

E4 continued

METAL DATA (*)

Station FELF1: 1982-1986; 4 analyses, Stations S3,S4: 1986; 4 analyses)

Sample Location		FELF1	S3	S4	S3+S4
PARAMETER	Detection Limits	Average	Average	Average	Average
Flow (L/s)		2.233	0.342	1.567	N/A
Silver, Unfilt.Total (as Ag)	0.005	0			
Aluminum, Unfilt.Total (as Al)	0.01	0.64			
Arsenic, Unfilt.Total (as As)	0.001	0			
Barium, Unfilt.Total (as Ba)	0.001	0.07075			
Beryllium, Unfilt.Total (as Be)	0.001	0			
Cadmium, Unfilt.Total (as Cd)	0.001	0	0	0.001	0.001
Cobalt, Unfilt.Total (as Co)	0.001	0.00475			
Cyanide, Avail.Unf.React. (as CN)	0.001	0.00175			
Chromium, Unfilt.Total (as Cr)	0.001	0.008	0.0035	0.013	0.0165
Copper, Unfilt.Total (as Cu)	0.003	0.04275	0.003	0.0135	0.0165
Mercury, Unfilt.Total (as Hg)	0.00001	0.000002			
Manganese, Unfilt.Total (as Mn)	0.001	1.5165	0.091	0.182	0.273
Molybdenum, Unfilt.Total (as Mo)	0.001	0.0085			
Nickel, Unfilt.Total (as Ni)	0.002	0.0045	0.009	0.0185	0.0275
Lead, Unfilt.Total (as Pb)	0.002	0	0.0125	0.013	0.0255
Antimony, Unfilt.Total (as Sb)	0.001	0			
Selenium, Unfilt.Total (as Se)	0.001	0			
Strontium, Unfilt.Total (as Sr)	0.01	1.8			
Titanium, Unfilt.Total (as Ti)	0.002	0.00625			
Thallium, Unfilt.Total (as Tl)	0.002	0			
Vanadium, Unfilt.Total (as V)	0.001	0.001			
Zinc, Unfilt.Total (as Zn)	0.003	0.12575	0.063	0.0155	0.0785
Total Metals Concentration (mg/L)		4.231	0.182	0.257	0.439
Total Metals Loading (kg/d)		0.8	0.01	0.03	0.04

* Data obtained from MOE files.

E4 continued

ORGANIC COMPOUND DATA (*)
Station FELF1: 1982-1986; 4 analyses, Stations S3,S4: 1986; 4 analyses)

Sample Location		FELF1	S3	S4	S3+S4
PARAMETER	Detection Limits	Average	Average	Average	Average
Flow (L/s)		2.233	0.342	1.567	1.909
Dichloromethane (Methylene Cl.)	0.0001	0.0080		0.09	0.09
Toluene	0.0001	0.0000		0.018	0.018
Total Organics		0.0081		0.108	0.108
Total Loading (kg/d)		0.00	0.00	0.01	0.01

* Data obtained from MOE files.

Loadings Summary	FELF1	S3	S4	S3+S4
Phenol	0.00	0.02	0.41	0.43
Metals	0.82	0.01	0.03	0.04
Organics	0.00	0.00	0.01	0.01
Total	0.82	0.02	0.46	0.49

The surface water loading is based upon the loading from stations S3 + S4. Station FELF1 is presented to illustrate the attenuation of the contaminants from the edge of the landfill area to the property boundary.

APPPENDIX E5 TOTAL LOADINGS, BRIDGE STREET LANDFILL, FORT ERIE

The total loading calculations are based upon the sum of the groundwater loadings (Appendix E3) and the surface water loadings (Appendix E4).

High Total Loadings Estimate

The high estimate of the total loading was derived by adding the high estimates of the groundwater loading and the surface water loading from stations S3 and S4.

L = L (groundwater) + L (surface water)
L = 0.02 + 0.49
L = 0.5 kg/d

Best Total Loadings Estimate

The best estimate of the total loading was derived by adding the best estimates of the groundwater loading and the surface water loading from stations S3 and S4.

L = L (groundwater) + L (surface water)
L = 0.01 + 0.49
L = 0.5 kg/d

Low Total Loadings Estimate

The low estimate of the total loading was derived by adding the low estimates of the groundwater loading and the surfacewater loading from stations S3 and S4.

L = L (groundwater) + L (surface water)
L = 0.004 + 0.49
L = 0.5 kg/d

APPENDIX F

DETAILED CALCULATIONS FOR THE CNR VICTORIA AVENUE LANDFILL, NIAGARA FALLS

APPENDIX F1 CONTAMINANT CONCENTRATIONS, CN RAIL LANDFILL NIAGARA FALLS

Overburden

CNR-1 Metals: 7401 ppb (not including Ca, Mg, Na, K, Fe)
Organics: none detected (PCB/Pesticide scan)

Since only a single analysis on a single well was available, the sum of the concentrations of the trace metals was used for the high, best and low estimates.

Therefore, C = 7401 ppb

Note: Well B1-11, drilled by Gartner Lee Limited for their study of the Cyanamid, Inc. landfills in Niagara Falls was used previously to estimate the loadings for Cyanamid's landfills. Therefore, if this well was used for CN Rail, double counting would result. Therefore, only CN Rails data were used here.

APPENDIX F2 GROUNDWATER FLUX, CN RAIL LANDFILL, NIAGARA FALLS

Overburden (Darcy's Law Approach, Q=k*i*A)

The data available for the CN Rail site were not sufficient for determining groundwater flux. Therefore data collected by Gartner Lee Limited for the Cyanamid Inc. landfills in Niagara Falls were used instead. The hydraulic conductivity values were determined for silty clay (5 tests) and silt and silty sand soils (23 tests). The best estimate of the values was chosen as the arithmetic average of the two , while the value for clay was used as the low estimate, and value for the silt and silty sand soils was used for the high estimate The hydraulic gradients were determined from the water table flow map prepared by Gartner Lee, 1988.

Estimate	Hydraulic Cond. "K" (m/d)	Hydraulic Gradient "i" (m/m)	Sat. Thick. "b" (m)	Unit Length "l" (m)	Groundwater Flux "Q" (m^3/d)	Groundwater Flux "Q" (L/d)
High	7.1E-01	0.06	10	300	1.28E+02	127,526
Best	3.6E-01	0.06	8	300	5.23E+01	52,255
Low	1.2E-02	0.06	6	300	1.31E+00	1,306

Note:

- A = (b) * (l)
- E = Exponent

APPENDIX F3 GROUNDWATER LOADINGS, CN RAIL LANDFILL, NIAGARA FALLS

The loadings calculations are based on the contaminant concentration data (Appendix F1) and the groundwater flux estimates (Appendix F2). Bedrock data was not available for this site.

Overburden

Since only a single analysis on a single well was available, the sum of the concentrations of the trace metals was used for the high, best and low estimates.

High Groundwater Loadings Estimate

L = C * Q(High)
L = 7401 * 1x10-9 * 127,526
L = 0.9 kg/d

Best Groundwater Loadings Estimate

L = C * Q(Best)
L = 7401 * 1x10-9 * 52,255
L = 0.4 kg/d

Low Groundwater Loadings Estimate

L = C * Q(Low)
L = 7401 * 1x10-9 * 1,306
L = 0.01 kg/d

APPENDIX F4 SURFACE WATER LOADING, CN RAIL VICTORIA AVENUE LANDFILL, NIAGARA FALLS

GENERAL CHEMISTRY DATA (* - 1982-1988, 7 data sets)

PARAMETER	Detection Limit	1982-1988 Average
Flow (L/s)	N/A	1
Chloride,Unfilt.React.(as Cl-)	0.1	67.033
Phosphorus,Unfilt.Total(as P)	0.004	0.278
Phosphates, Reactive (as P)	0.003	0.001
TKN,Unfilt.React.(as N)	0.06	
NO3+NO2 (as N)	0.005	0.325
NO2 (as N)	0.003	0.017
NO3 (as N)	0.05	0.225
Solvent Extractables	1	0.667
Phenolics,Unf.React. (4AAP)	0.0002	0.0002
Polynucl.Arom.H-carbons (PAH)	N/A	0.000
Total (mg/L)		69.682
Phenol (mg/L)		0.0002

* Data obtained from MOE files.

F4 continued

METAL DATA (* - 1982-1988, 7 data sets)

PARAMETER			Detection Limit	1982-1988 Average
Flow (L/s)				1
Silver,	Unfilt.Total	(as Ag)	0.005	0.000
Aluminum,	Unfilt.Total	(as Al)	0.01	13.388
Arsenic,	Unfilt.Total	(as As)	0.001	0.010
Barium,	Unfilt.Total	(as Ba)	0.001	0.121
Beryllium,	Unfilt.Total	(as Be)	0.001	0.000
Cadmium,	Unfilt.Total	(as Cd)	0.001	0.008
Cobalt,	Unfilt.Total	(as Co)	0.001	0.007
Cyanide,	Avail.Unf.React.	(as CN)	0.001	0.000
Chromium,	Unfilt.Total	(as Cr)	0.001	0.018
Copper,	Unfilt.Total	(as Cu)	0.003	0.076
Mercury,	Unfilt.Total	(as Hg)	0.00001	0.00047
Manganese,	Unfilt.Total	(as Mn)	0.001	2.187
Molybdenum,	Unfilt.Total	(as Mo)	0.001	0.012
Nickel,	Unfilt.Total	(as Ni)	0.002	0.086
Lead,	Unfilt.Total	(as Pb)	0.002	0.039
Antimony,	Unfilt.Total	(as Sb)	0.001	0.000
Selenium,	Unfilt.Total	(as Se)	0.001	0.000
Strontium,	Unfilt.Total	(as Sr)	0.01	1.110
Titanium,	Unfilt.Total	(as Ti)	0.002	0.220
Thallium,	Unfilt.Total	(as Tl)	0.002	0.000
Vanadium,	Unfilt.Total	(as V)	0.001	0.027
Zinc,	Unfilt.Total	(as Zn)	0.003	1.433
Total (mg/L)				18.741

* Data obtained from MOE files.

F4 continued

ORGANIC COMPOUND DATA (* - 1982-1988, 7 runs)

PARAMETER	Detection Limit	1982-1988 Average
Flow (L/s)		1
Dichloromethane(Methylene Cl.)	0.0001	0.002033
Chloroform	0.0001	0.000167
Tetrachloroethylene	0.0001	0.000100
Benzene	0.0001	0.000067
Toluene	0.0001	0.000067
ortho-Xylene	0.0001	0.000100
meta-Xylene	0.0001	0.000100
para-Xylene	0.0001	0.000100
A-BHC(A-Hexachlorocyclohexane)	0.000001	0.000001
Alpha-Chlordane	0.000002	0.000003
Dieldrin (HEOD)	0.000002	0.000003
Endosulfan II (Thiodan II)	0.000004	0.000003
Oxychlordane	0.000002	0.000003
Hexachlorobenzene (HCB)	0.000001	0.000001
Total PCB's	0.00002	0.000063
Total (mg/L)		0.00281

* Data obtained from MOE files.

SURFACE WATER LOADINGS (kg/d)

Phenol	0.00002
Metals	1.6
Organics	0.0002
Total	1.6

APPENDIX F5 TOTAL LOADINGS, CN RAIL VICTORIA AVENUE LANDFILL, NIAGARA FALLS

The total loading calculations are based upon the sum of the groundwater loading given in Appendix E3, and the surface water loading presented in Appendix E4.

Overburden

High Total Loadings Estimate

L = L(groundwater, high) + L(surface water, total)
L = 0.9 + 1.6
L = 2.5 kg/d

Best Total Loadings Estimate

L = L(groundwater, best) + L(surface water, total)
L = 0.4 + 1.6
L = 2.0 kg/d

Low Total Loadings Estimate

L = L(groundwater, low) + L(surface water, total)
L = 0.0 + 1.6
L = 1.6 kg/d

APPENDIX G

LIST OF U.S. EPA PRIORITY POLLUTANTS

APPENDIX G: PRIORITY POLLUTANT LIST

This list of 131 chemicals includes 13 metals, 116 organic chemicals, cyanide and asbestos.

acenapthene
acrolein
acrylonitrile
benzene
benzidine
carbon tetrachloride
chlorobenzene
1,2,4-trichlorobenzene
hexachlorobenzene
1,2-dichloroethane
1,1,1-trichloroethane
hexachloroethane
1,1-dichloroethane
1,1,2-trichloroethane
1,1,2,2-tetrachloroethane
chloroethane
bis(chloromethyl) ether
bis(2-chloroethyl) ether
2-chloroethyl vinyl ether
2-chloronaphthalene
parachlorometa cresol
chloroform
2-chlorophenol
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
3,3-dichlorobenzidine
1,1-dichloroethylene
1,2-trans-dichloroethylene
2,4-dichlorophenol
1,2-dichloropropane
1,2-dichloropropylene
2,4-dimethylphenol
2,4-dimethylphenol
2,4-dinitrotoluene
2,6-dinitrotoluene
1,2-diphenylthydrazine
ethylbenzene
fluoanthene
4-chlorophenyl phenyl ether
4-bromophenyl phenyl ether
bis(2-chloroisopropyl) ether
bis(2-chloroethoxy) methane
methylene chloride
methyl chloride
methyl bromide
bromoform
dichlorobromomethane
trichlorofluoromethane
dichlorodifluoromethane
chlorodibromomethane
hexachlorobutadiene
hexachlorocyclopentadiene
isophorone
napthalene
nitrobenzene
2-nitrophenol
4-nitrophenol
2,4-dinitrophenol
4,6-dinitro-o-cresol
N-nitrosodimethylamine
N-nitrosodiphenylamine
N-nitrosodi-n-propylamine
pentachlorophenol
phenol
bis(2-ethylhexl) phthalate
butyl benzyl phthalate
di-n-butyl phthalate
di-n-octyl phthalate
diethyl phthalate
dimethyl phthalate
benzo(a)anthracene (1,2-benzathracene
benzo(a)pyrene
3,4-benzofluoranthene
benzo(k)fluoranthene
chrysene
acenaphthylene
anthracene
benzo(ghi)perylene
fluorene
phenanthrene
dibenzo(a,h)anthracene
indeno (1,2,3-cd) pyrene
pyrene
tetrachloroethylene
toluene
trichloroethylene
vinyl chloride
aldrin
dieldrin
chlorodane
4,4-DDT
4,4-DDE
4,4-DDD
a-endosulfan-Alpha
b-endosulfan-Beta
endosulfan sulfate
endrin
endrin aldehyde
heptachlor
heptachlor epoxide
a-BHC-Alpha
b-BHC-Beta
r-BHC(lindane)-Gamma
g-BHC-Delta
PCB-1242
PCB-1254
PCB-1221
PCB-1232
PCB-1246
PCB-1260
PCB-1016
toxaphene
antimony
arsenic
asbestos
beryllium
cadmium
chromium
copper
cyanide
lead
mercury
nickel
selenium
silver
thallium
zinc
2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD)

APPENDIX G Continued: PARAMETERS OF CONCERN

The following 14 parameters heve been selected by the Niagara River Toxics Management Plan for 50 % reduction.

Benzo(a) Anthracene
Benzo(a) Pyrene
Benzo(b) Fluoranthene
Benzo(k) Fluoranthene
Hexachlorobenzene
Tetrachloroethylene
PCB's
Mercury
Mirex
Chyrsene
Chlordane
DDT
Dieldrin
Octochlorostyrene